SOME ASPECTS OF CO-OPERATION IN FARMING

WITH SPECIAL REFERENCE TO

A GROUP OF ARABLE FARMS IN THE EAST OF SCOTLAND

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ABSTRACT

The section of British Agriculture for which farm amalgamation may be an economic necessity is examined, and the incidence of and rate of farm amalgamation since 1875 is demonstrated. It is suggested that the effects of farm amalgamation are similar to the effects of a change in the scale of farming and evidence relating to the economies and diseconomies of scale is examined. Action by official bodies to reduce the number of uneconomic farms, and by farmers to obtain the advantages of larger size without increasing the size of farms, is discussed.

The farms used in the investigation, the area in which they lie, the climate and the type of farming, are described. The general method of investigation and the requirements to be met in constructing the planning model are discussed, and the effect on farm planning solutions of ignoring factors which in practice affect decision making, is demonstrated.

Work on improving the available linear programming program to obtain the required output, to improve data input and to obtain greater speed and flexibility in computation, is described. The construction of the matrix comprising the planning model is outlined, with fuller discussion of three areas - the representation of working capital, regular labour and farm machinery selection. The calculation of labour supply involved an assessment of the effect of weather on the time available for farm work. The method of assessment, and the effect of applying the resulting criteria to meteorological data recorded in three areas, have been described in published articles which are reproduced as appendices.

The results of the investigation are presented with the intention of providing two types of comparison - the effect on the individual farms of various planning assumptions, and the effect on the 2811 acre block of land of farming it as six units or as one farm, again subject to various assumptions. Comparisons are shown to indicate the effects of introducing dairying, of having limited or unlimited availability of capital, and of using high output

equipment on the amalgamated unit.

The possible effect of the current system of taxation on the gross profits derived from the individual farms and from the amalgamated unit is investigated, in order to provide a comparison of the net spendable incomes available to individuals.

It is concluded that the minimum gross profit improvement obtainable by amalgamation of these particular farms is insufficient to offset the taxation disadvantage to which the single unit business could be subject, but that in practice the gross profit advantage of amalgamation would depend upon the farming and business ability of the people involved and their command of capital, both as individuals and as a group. Possible managerial and business expansion advantages, and social advantages and disadvantages, are outlined.

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PART ONE

I N T R O D U C T I O N

1.0 The need for changes in the structure of farm businesses

1.01 " . . . the capacity of a business to remain viable in an expanding economy . . . depends on the production of a profit net of tax which is large enough to provide both for drawings and for capital growth, the latter being essential to counteract inflation and to finance the ever increasing profit earning potential which is needed if the living standards of the farmer are to rise in line with those of others in the community." This passage from an article by Tracey (1) expresses a standard which many farms and farmers are unable to attain.

Assuming that for the living standards of a farmer to rise in line with those of the community at large, his spendable income must rise at 3% per annum, and that the return on marginal capital is the same as the average return on capital, at 13%, then his capital will also have to increase by 3% per year. Taking £600 per year as a minumum cash consumption for a family in 1965 (i.e. just above the poverty limit suggested by Sturrock (2), and assuming an average tax rate of 15%, then the taxable farm profit required to provide £600 in the first year, increasing at 3% annually thereafter, is £969.

YEAR 1

Return on £7,453 @ 13% =	Taxable farm profit	=	£969
	Tax @ 15%		145
	Net Income		824
	Capital retention 3% of £7,453		224
	Cash drawn		600

YEAR 11

Return on £7,677 @ 13% =	Taxable farm profit	=	£998
	Tax @ 15%		150
	Net Income		848
	Capital retention 3% of £7,677		230
			£618

(= £600 x 1.03)

1.02 It is difficult to assess how many farmers in Britain fail to reach this level of profit. In general, a farm with 90-100 acres of reasonably good land and with a sufficient intensity of business to give work for about 2 men, might be required. Sturrock (2) gives the average Net Income from a group of farms of 50-100 acres in an East Anglian sample, as £1,043, but comments that one third of these had Net Incomes below the poverty line of £600. An O.E.C.D. report (3) indicates that in 1960 half the farms in England and Wales of 50-100 acres had a Net Farm Income of £800 or less; the net income on farms of 50-100 acres varied by type of farming from £497-£1450; measuring size of business by the number of standard man days required, with 280 man days = one full time man, farms requiring 501-800 man days had Net Incomes of around £800; in Scotland in 1961-62, 75% of farms requiring 275-750 man days had Net Incomes of less than £1000. Hendry (4) shows Net Incomes of £927-£1185 from Scottish farms requiring 750-1500 man days.

1.03 The number of agricultural holdings in the United Kingdom requiring less than 600 man days, or approximately 2.2 men, is estimated as 427,400 (3). Of these, 328,000 require fewer than 275 man days, and are normally regarded as only part time, the occupier having additional income from other sources. Work by Ashton and Cracknell (5), shows that about

16500 holdings in England and Wales which require fewer than 250 man days, provide the only income for their occupiers. Hendry (6) estimates that 2000 holdings in Scotland of less than 275 man days provide the whole income of the occupiers, while the Ministry of Agriculture for Northern Ireland estimate that 16,000 farmers are fully dependent on holdings providing less than full time employment. Thus there would appear to be about 99,400 farms requiring from 1 to 2.2 men, and 34,500 which give less than full time work for one man, but are the only source of income - a total of 134,000, or say 120,000 potentially non-viable farms, assuming that about 14,000 of these give full employment to two or more men. Compared to the figure of 99,400 calculated above, a Ministry of Agriculture survey (7) estimates the number of full time farms requiring fewer than 600 man days, to be 112,000.

The presence of a high proportion of low income farms is a situation common to all countries in Western Europe and North America (3). It is also one which, in Britain at least, has long been present. The advent of the turnip about 1725 started the need for enclosure to protect the better crops and improved ground, and this is part led to an increase in the general scale of farming. Arthur Young commented in 1796 that "Small farms . . . below £100 per year (around Reading for example) are . . . . very unprofitable . . . the occupier poor and distressed and their farms in bad order." (8)

1.04 By the introduction in 1959 of the Small Farmer Scheme, an attempt was made to deal specifically with the problem of small businesses and low incomes in British agriculture. This scheme made available grants of up to £1000 per farm, to intensify and increase the size of small farm businesses. Apart from this, the price support system aims to keep farm incomes in general at an acceptable level, and could be biased towards those products - eggs, pig and poultry meat, and milk - which form a large part of the output of small farms.

Sturrock (2), however, points out that such methods of tackling the small farm problem are limited by the market for these intensive products, and that in any case the 'small' farm is unable to fully utilise all equipment, and therefore tends to be over capitalised and labour inefficient - that a better approach might be by the provision of grants for farm amalgamation and the re-settlement of redundant farmers. Maunder (9) similarly comments that price support and subsidies do not cure the agricultural ill of declining real net income - attempts to increase the numerator of total net income are doomed to failure given the present elasticity of demand and increase in agricultural production. The alternative is to reduce the denominator of farmer numbers, by encouraging the amalgamation of uneconomic farms.

2.0 Recorded progress of farm amalgamation

2.01 Amalgamation of farms leading to a reduction in total numbers has been taking place in Britain for as long as there have been records of farm numbers. In 1885 there were 453,000 holdings in England and Wales, and by 1955, the number had fallen to 370,000. The rates of change of numbers in different size groups of farms, and fluctuations in the rates of change are illustrated in Figure A which includes, in broken lines, Professor Britton's (10) projection of farm numbers up to 1976.

Hunt (11) notes that in the late 1890's half the farmland of England and Wales was in holdings of "about 160 acres", but that large farms accounted for a diminishing proportion of land until about 1933, due possibly to the break up of farms of more than 300 acres. In the early 1930's this trend was sharply reversed, and from 1933 to 1949 the proportion of land in farms of over 300 acres increased from 22% to 25%.

Long (12) suggests that the industrial revolution in Britain, by providing opportunities for alternative employment, made possible the emergence of large farms by the middle of the nineteenth century, especially in the cereal growing areas. From 1875-1939, farms of 50-100 acres increased from 44842 to 50117 at the expense of those greater than 300 acres, which decreased in numbers from 15579 to 11259. From 1939-1964 the trend reversed, large farms over 300 acres increasing to 14,536 and the 50-100 acre group falling in numbers to below the 1875 level, at 43,433. These changes seemed to correspond to the long term state of agricultural prosperity.

2.02 The current decrease in the number of full time farms in England and Wales is estimated by the Ministry of Agriculture in 1966 (7) to be 2-3000 per year, or 0.9-1.36% while Britton (10) states that the average rate of loss of full time farms from 1961-66 is 5,777 per year, or 3.4% per

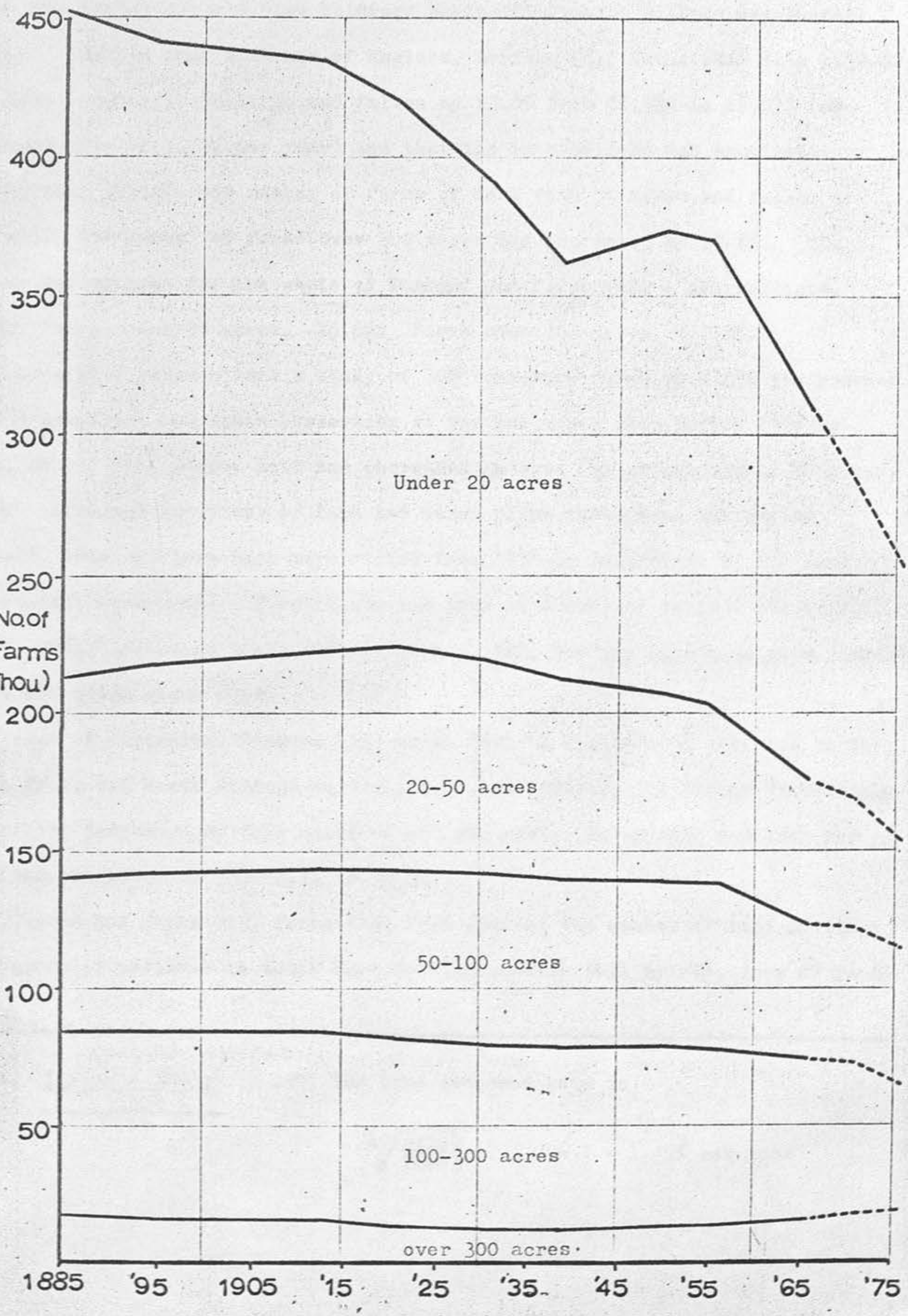

FIGURE A: No. of farms in England and Wales by size groups; 1885-1965-1976 year, the number of part time holdings having fluctuated without any overall change. In the East Midlands of England, Britton (13) found that from 1952-62 the total number of holdings had fallen by 13.8% from 32,588 to 28,093 (an average* rate of 1.38% per year) and that the rate of loss was accelerating. In the same period, the number of farms of less than 50 acres had fallen by 18% while the number of farms over 300 acres had increased by 10.4%. The comparable changes for the whole of England and Wales were - all holdings, -12%; Farms under 50 acres, -16.6%; Farms over 300 acres, +13.3%.

Long (12) reports that a study of 300 Yorkshire farms of which the present (1965) occupiers had taken possession at various times from before 1926 to 1956, showed that almost half had increased in size (by an average of 68%) by 1965. Although additions of land had taken place throughout the period 1926-65, this had been much more marked from 1956-65 regardless of the date of original occupancy. Farmers who had been in occupancy in 1926 for example had by 1965, increased their farm acreage by 64%, but two thirds of this increase had taken place since 1956.

Also in Yorkshire, Simpson (14) shows that in a sample of parishes in the East, West, and North Ridings during the period 1962-66, the number of holdings per parish decreased by from -3.9% to -10.6%, while the average acreages per farm had increased by from 4.3% to 10.6%.

Thorns and Mason (15) found that from 1942-64 the number of farm holdings in a group of parishes in South East Nottinghamshire fell by 27%, from 67 to 49.

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* i.e. $\dfrac{\left(\dfrac{32588 - 28093}{32588}\right)}{10} \times 100$ The true compound rate is

$$\sqrt[10]{\frac{32588}{28093}} - 1 = 1.49\% \text{ per year}$$

Of the 43 farms which existed throughout the period, 42% had increased in size and 26% were unchanged, while 32% had decreased in size.

Urquhart (16) in a study of the amalgamation of farms in two parishes in Aberdeenshire from 1870-1960, found that the disappearance of smaller farms and crofts had reduced the number of holdings in the area studied from 237 to 129, an average annual rate of 0.506% (compound rate 0.67%).

This overall decrease however masks fluctuations which are shown in Table 1. The trends shown correspond more or less with Long's comments (12) on long term agricultural prosperity, although as Urquhart points out, improvement in transport and communications would have had a considerable effect in such an area as he studied.

TABLE 1

PERIOD	PERCENTAGE DECLINE PER YEAR		
	PARISH 1	PARISH 2	TOTAL
1870 - 1892	0.31	0.04	0.16
1892 - 1911	0.69	0.33	0.48
1911- 1921	1.85	0.16	1.00
1921 - 1929	4.51	3.67	4.06
1929 - 1939	0.55	+0.43	0.00
1939 - 1946	1.71	1.77	1.74
1946 - 1960	1.09	0.72	0.88

TABLE 1: Annual Rates of Decline in Numbers of Holdings in different periods in two Aberdeenshire Parishes.

2.03 Changes in farm structure are also evident in Western Continental

Europe and North America, although there is variation between areas in the size of farm which is increasing or decreasing and in the rate of change. Mosher (17) records that farm numbers in Illinois decreased from 264,151 in 1900 to 175,543 in 1955. The number of farms of under 10 acres, especially very small ones, increased considerably, while farms of 10-15 acres, 50-100 acres and 100-180 acres decreased overall by 52% in the period, and farms of over 260 acres increasing by 67%.

Heady, McKee and Heady (18) record that in Iowa State, U.S.A., farms of from 20-100 acres decreased in number from 1910 to 1950, while farms of 100-175 acres increased from 1910 to 1920 and then decreased from 1920 to 1950. Farms of 175-260 acres increased from 1910 to 1930 and thereafter decreased in number until 1950. Farms of over 260 acres, however, became fewer from 1910 to 1920, and then increased from 1920 to 1950.

Wetterhall (19) notes that in Sweden in 1961 total farm numbers were 252,573 - 85.3% of the 296,227 holding existing 17 years earlier in 1944, and 81% of the number in 1928, 33 years previously. He also points out that in 1961 farms of 5-50 acres were declining in number and those of 50-250 acres were increasing, but that those of over 250 acres were also decreasing.

Figure B, illustrating recent changes in farm size distribution, in O.E.C.D. countries, is reproduced from the O.E.C.D. report on "Low Incomes in Agriculture" (3) Page 31-32.

A general conclusion might be drawn that the rate of farm consolidation has increased in more recent times. In Britain, from the trend shown in Figure A and from the observations on the expansion of some Yorkshire farms mentioned by Long (12), it might be suggested that the rate of consolidation has been higher since about 1955. A possible reason for this is put forward by Shemilt (20) who after comparing relative changes in efficiency in some large and small farms in Scotland from 1948/9 to 1955/6 concludes that during the period considered many small farms had benefitted considerably from their relatively high rate of increase in technical efficiency made possible by their

CHANGES AND DISTRIBUTION OF FARM HOLDINGS BY SIZE GROUPS

(The height of columns represent the percentage decrease or increase in the number of holdings of that size during the period concerned. The width of columns correspond to the percentage distribution of holdings of that size at the end of the period concerned.)

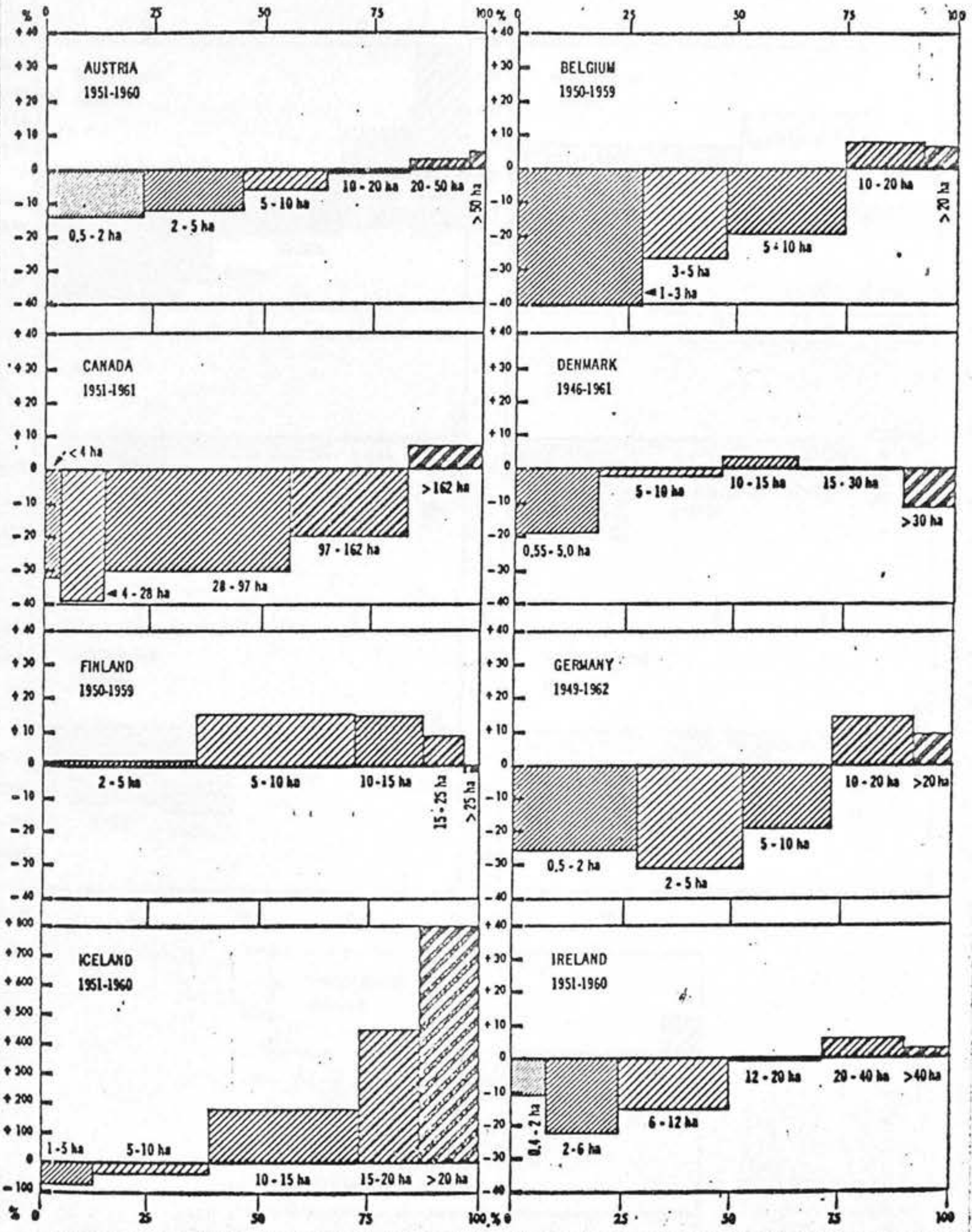

FIGURE B (1) Changes in Farm Size Distribution in O.E.C.D. Countries.

CHANGES AND DISTRIBUTION OF FARM HOLDINGS BY SIZE GROUPS

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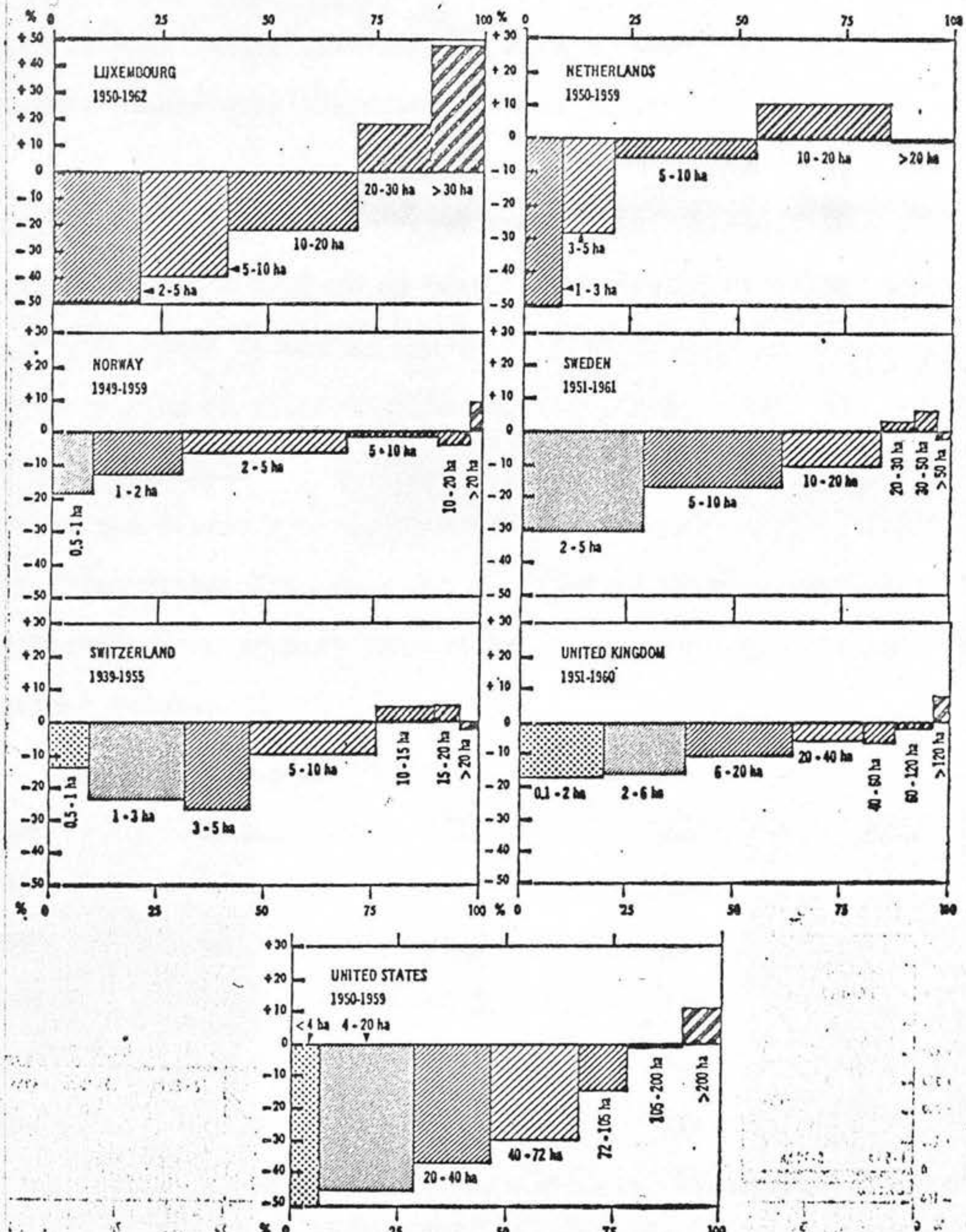


FIGURE B (11) Changes in Farm Size Distribution in O.E.C.D. Countries.

adoption of up to date techniques which larger farmers had already introduced before this period. He suggests that once they have caught up in the adoption of such techniques they will be unable to continue raising their physical efficiency faster than that of larger farms, and that the need for organisational change will therefore be greater than in the past.

2.04 Looking ahead, Britton (10) forecasts a 100% increase from 1966-1976 in the proportion of land in Britain in farms of over 500 acres, with farms of 300-500 acres remaining constant in total area and farms of less than 300 acres decreasing in proportionate land use from 67% to 58%. This is illustrated in Figure C.

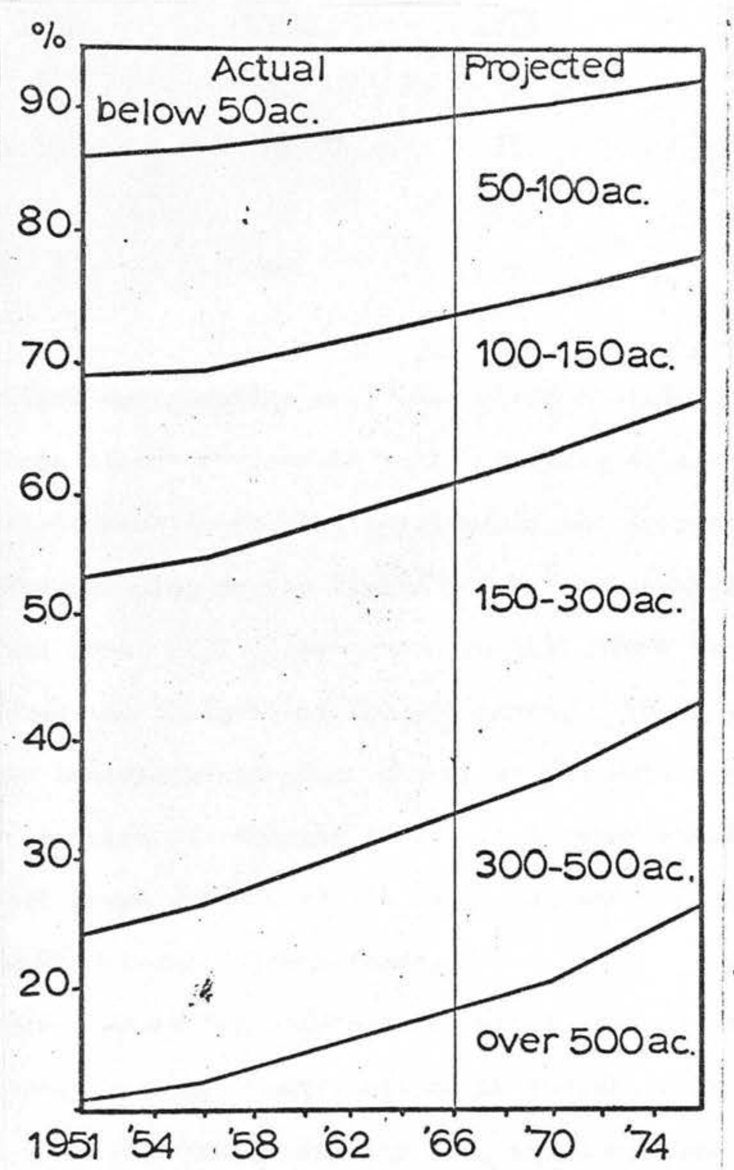
Harrison and Alexander (21) record the changes from 1961 to 1967 in the numbers of farms within five size groups based on Standard Man Days, and using the Markov Chain process project further changes by 1973 and 1979, which are summarised below.

% of Farms by S.M.D. Groups

S.M.D.	1961	1967	1973	1979
50-199	38.2	34.3	30.0	25.7
200-449	41.7	38.9	35.4	31.4
450-599	9.7	8.8	7.9	7.0
600-1199	9.3	15.8	22.3	28.5
1200+	1.0	2.3	4.4	7.5

Lovering, Oddie and Rokosh (22) after studying structural changes in farming in the Red Deer area, Alberta, Canada, for the period 1926-67, also use the Markov Chain probability matrix to project changes in five year periods from 1967 to 1982. Farm grouping was based on the P.M.W.U. (Productive Man Work Unit = Amount of directly productive work done by a

Percentage of U.K. Farmland occupied by farms of various size groups



YEARS

FIGURE C: Projection of farm numbers (by size groups) in Britain 1966-76.

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typical operator using typical production methods, in a ten hour day), the results of this calculation being shown below.

% of Farms by P.M.W.U. Groups

P.M.W.U.	1962	1967	1972	1977	1982
Under 400	62	43	32	23	17
401-600	19	19	15	11	8
601-800	11	19	19	17	13
Over 801	8	19	34	49	62

2.05 Although most farm amalgamation must come about by individual farmers adding convenient blocks of land to their existing holdings, as they become available, estate owners are also involved in the process of rationalisation. For example, on the Vaynol Estate in Caernarvonshire (reported by Jones and Jones (23)) there were in 1957 22000 acres comprising 359 farms of 5-30 acres and 51 farms of 100-300 acres. These were to be rationalised with the assistance of grant aid under the Farm Improvement Scheme, a survey having been carried out showing 32 economic farms which would be unaltered, 19 economic farms which would be enlarged, and 359 small units on 15,000 acres which would produce 77 new farms.

It is not, however, generally possible for estate owners to proceed with amalgamation as actively as they might wish, as is indicated by a survey carried out in 1965 by Nottingham University (24) on 72 estates in England and Wales. Because of social and legal considerations, changes in estate structure were normally possible only on the vacation of rented holdings, and this did not often occur in the time sequence necessary to allow optimum fulfillment of rational amalgamation. There were three basic procedures - sale of estate holdings, enlargement of estate holdings, and enlargement of home farms - and all might be employed in a process which might require several stages of adjustment to arrive at the desired result.

In relation to the difficulties mentioned due to legal and social problems, it is interesting to note the observations made by Grisewood (25) in relation to Inverernie Estate in Inverness-shire, on which eight hill farms were taken in hand (with suitable compensation) just before legislation was passed giving security of tenure. Buildings were improved and stocking was considerably increased, and the community expanded from 22 adults and 9 children to 28 adults and 28 children. Good wages were paid, a pension scheme was introduced, the people had more free time than when self-employed, and on the whole the social climate was greatly improved.

3.0 The Effects of Amalgamation

3.01 Since the result of the amalgamation of two farms, is one larger farm, the physical and economic benefits and disadvantages of amalgamation may be considered as similar to those of an increase in size.

It is noted in several publications (e.g. Faris (26)) that the phrase 'Economies of Scale' is sometimes used as a synonym for 'Economies of Size'. Scale is defined* as a 'system of precise proportional reproduction, enlargement, or diminution'. An increase in scale therefore requires that the component parts of the subject remain in the same ratio, at least with respect to their functional measurements. To utilise an illustration from Boulding (27) - In relation to its length, a flea can jump a height equivalent to a man jumping over the Capitol Building in Washington. If however the flea grew until it was six feet long, it could jump very little, since the strength of its leg muscles is proportional to their cross section (area) while its weight is proportional to volume.

Thus the flea has not in fact increased in scale in respect of its functional measurements, which as far as jumping is concerned, are weight and leg strength. It has however increased in size, which is a much less

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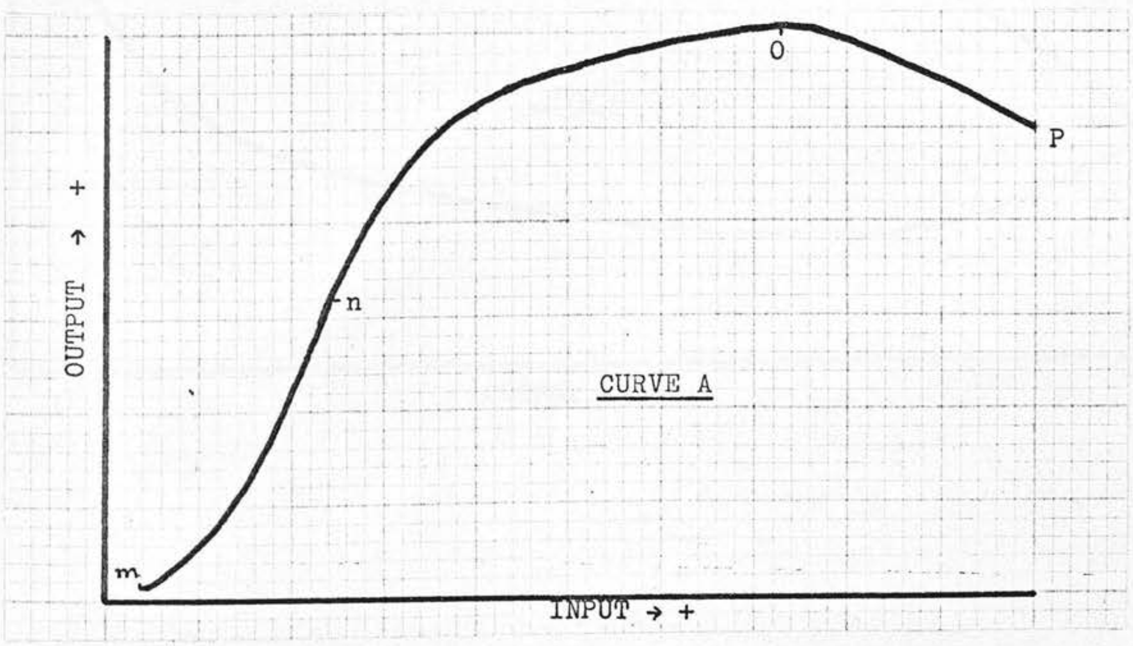
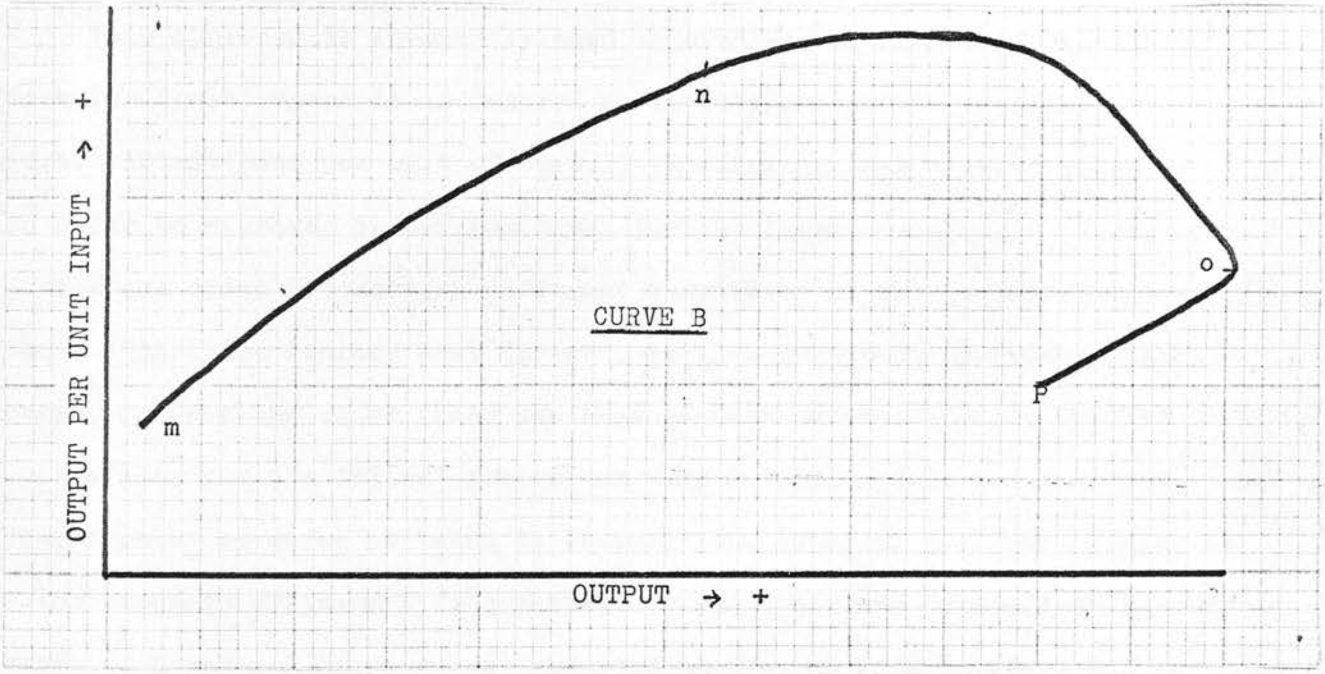
* Penguin English Dictionary, 1965.

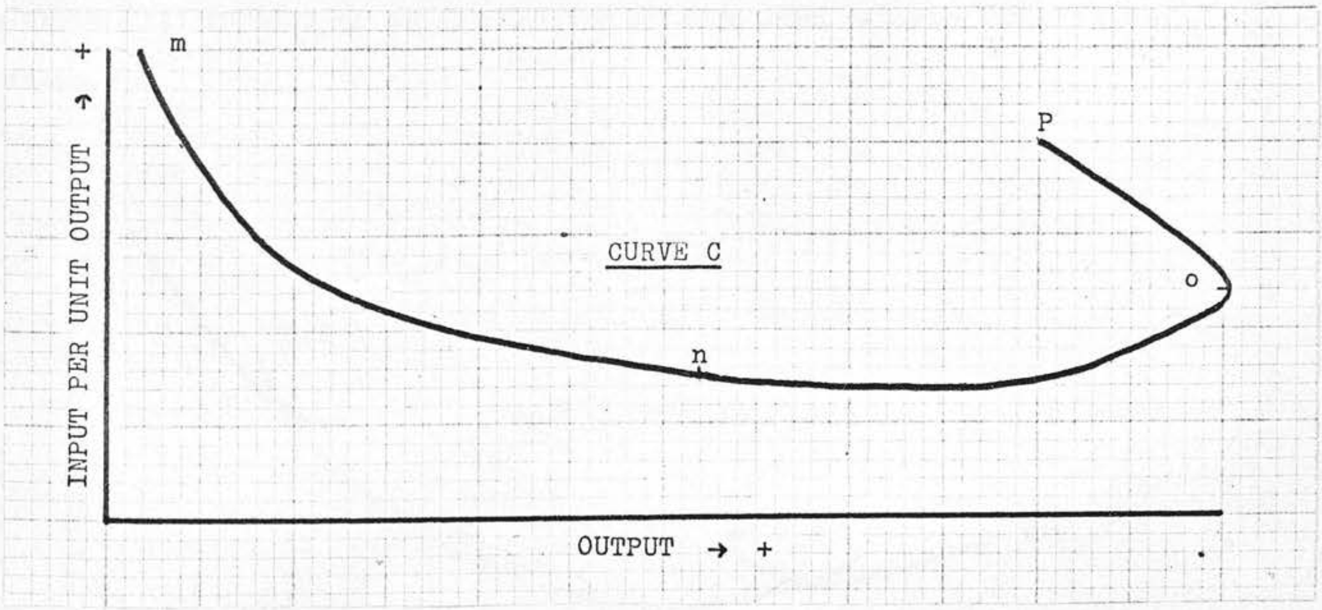
precise concept allowing variation of the ratios of one component part to another within the whole. As Upchurch (28) says, "One source of lack of precision relates to confusion between economies of scale and economies of variable proportions. It is difficult to see how one can get economics of scale without changing the input mix, - - - much of the time we are talking only about variable proportions when we think we are talking about economics of scale."

The 'law' of variable proportions, diminishing returns, or eventually diminishing marginal physical productivity postulates that "If ever increasing amounts of a variable factor are applied to a fixed quantity of the other factors, the amount added to the total product by each additional unit of the variable factor will eventually decrease; after this point has been reached each additional unit of the variable factor will add less to the total product than did the previous unit." (Livsey (29)) This statement can be illustrated graphically as shown below (Curve A). Section (m, n) represents an area of increasing marginal returns, Section (n, o) the area of decreasing marginal returns and from o to p the curve denotes negative marginal returns (as would occur for example if the amount of fertiliser applied to an acre of barley is constantly increased - a point comes where yield is depressed by additional fertiliser).



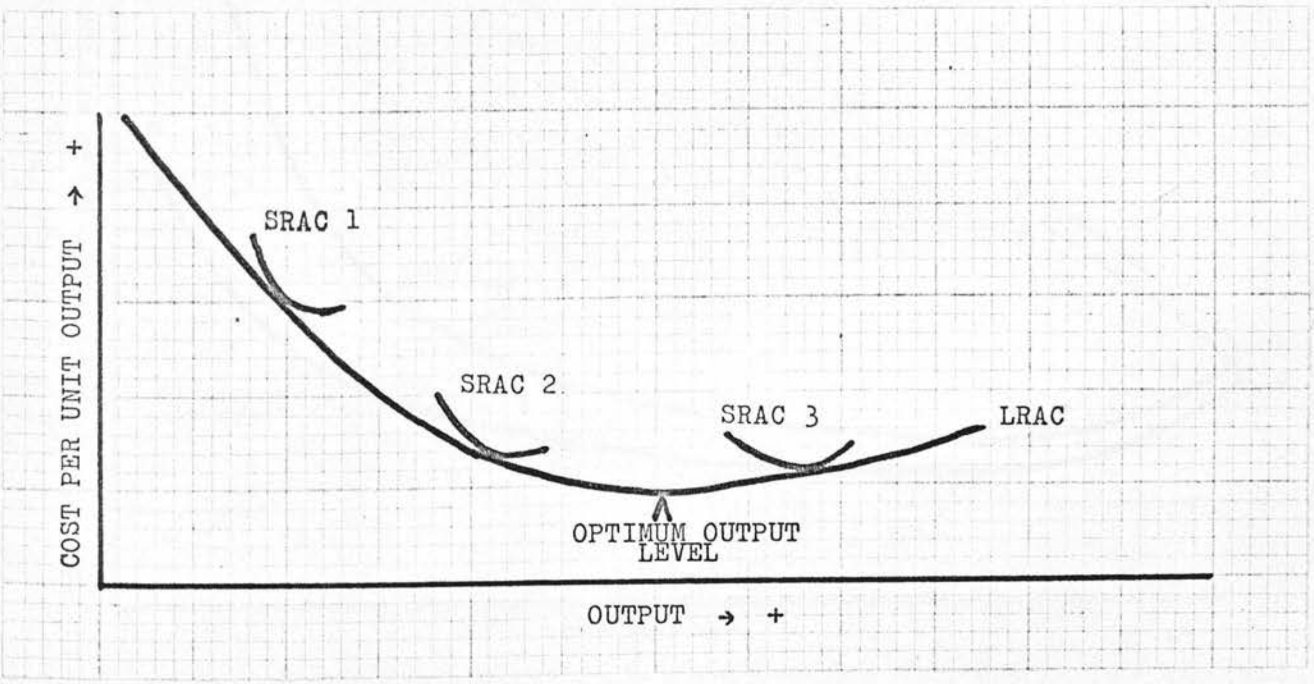
The same information can be expressed as the relationship between (Output per unit of the Variable Input Factor) and Output level (Curve B); or as the inverse of this, the relationship between (Variable Input Factor per unit of Output) and Output level (Curve C), as illustrated below. Again (m, n) denotes increasing marginal returns, (n, o) = decreasing marginal return and (o, p) = negative marginal return.



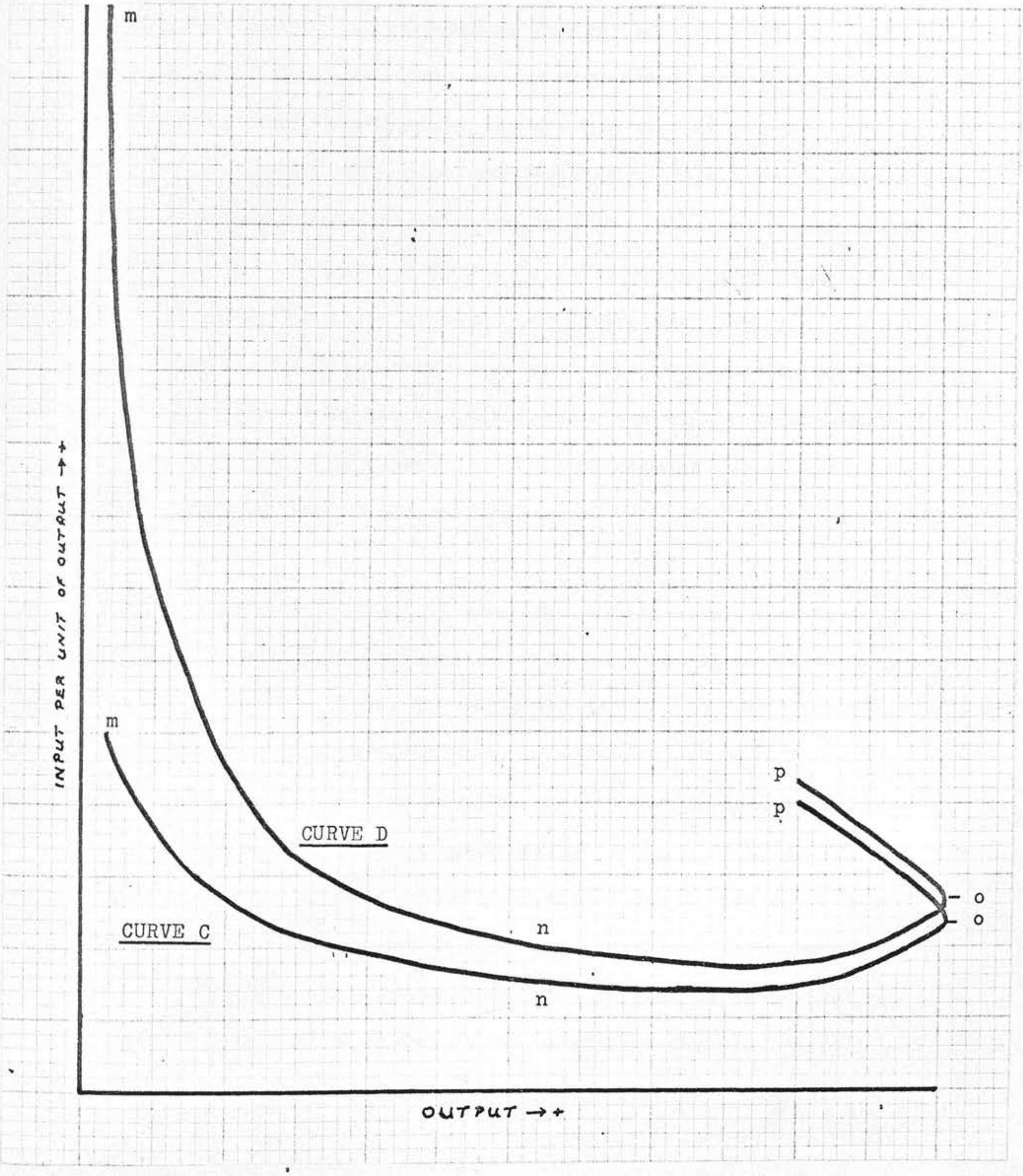


Where input and output are measured in monetary terms, this last relationship is normally known as the 'Average Cost Curve' each point on the curve indicating the average cost per unit of output at a particular output level. At the lowest point on the curve the unit cost is minimal, denoting the point of optimum economic input of the variable factor in relation to the available amount of fixed factors.

This approach is frequently used in studies relating to Economies of Size (or Scale) where it is desired to investigate economic efficiency (i.e. minimal cost per unit of output) in relation to a 'fixed' resource in order to discover an optimum level for the fixed resource. Average Cost Curves are drawn for several different quantities of the 'fixed' factor and these 'Short Run Average Cost Curves' are then connected by a tangential curve, or envelope curve (Long Run Average Cost Curve, since it implies that in the long run the 'fixed' factor can vary - e.g. acreage can increase), the lowest point of which is taken to indicate the level of the fixed factor at which economic efficiency is greatest. This technique is employed by, for example, Dixey and Maunder (30) in deciding optimum farm acreage, and by Jawetz (31) as part of an examination of farm size relationships in dairy farms.



Frequently in practice the variable input factor has in fact two cost elements - a constant element which is incurred before any output is obtained, and a true variable element. The inclusion of this constant in the Average Cost Curve tends to change the shape of the curve from U-shaped to L-shaped. This is illustrated in Curve D below, which is derived from Curve C by adding an initial constant.



The type of relationship involved in Curve D is noted by Howell (32) as applying to the cost of livestock production, and is implicit in the labour requirements of livestock production described by Langvatn (33). It is the basis of the relationship between field size and shape, and the work rate of implements, discussed by Edwards (34), the practical consequences of which are described by Davies and Dunford (35).

The Curve D relationship is employed by Carter and Dean (36) in investigating optimum size of farm business in cash crop farms in California; by Dean and Carter (37) in investigating the optimum size of peach orchards; by Michalson (38) in investigating economies related to farm size in Washington; by Mosher (17) in demonstrating labour costs, and machine costs per acre on Illinois farms, by Heady, McKee and Heady (18) in investigating production cost economies in relation to farm size in Iowa; by Warley and Baron (39) in studying potato packaging costs; and many others. The farmer who takes on another farm, although he may not think of it so, is taking advantage of the relationship by applying an increased number of acres to a fixed management factor, and to a very often fixed quantity of labour and machinery.

3.02 The basis of economies of size as described in the last section, is an improvement in economic efficiency, in cost per unit value of output, as size of business increases. There are basically two methods used in investigating the existence and effect of this phenomenon.

(a) Random stratified sampling of existing farm businesses, possibly with subsequent regression analysis of the data. Faris (26) considers this to be a rather poor method due to the existence of variable factors which depend upon individual farm operators. Carter and Dean (36), having used both methods in investigating size economies on cash crop farms, suggested that the results obtained by sampling and regression analysis, were suspect.

(b) Economic engineering synthesis, wherein experimental and standard data are used to build a model typifying the circumstances being investigated. Faris (26) considers this method to absorb more time initially than method (a), but to be subsequently much more flexible.

3.03 Simpson (14) from a survey in Yorkshire showed that for farms in each of four type groups, Gross Output per £100 Total Inputs increased (i.e. Input/£100 Gross Output decreased) as business size increased. A report by the University of Newcastle Agricultural Adjustment Unit (40) notes that a survey of 2177 farms showed Gross Output per £100 Input to increase fairly markedly up to 600-1200 S.M.D. with no obvious difference above that level. Mosher (17), investigating farms in Illinois, U.S.A., notes with particular reference to labour and machinery costs per acre, that "The efficiencies due to larger size of farms appeared to level off at about 260 acres." Raeburn (41) comparing five acreage groups (20-50 acres; 50-100 acres; 100-150 acres; 150-300 acres; 300 + acres) of farms in East Anglia, found little consistent variation in total inputs per £1000 of gross income, the tendency being if anything towards a rise in input costs per £1000 output as farm acreage increased up to 150 acres.

Dean and Carter (37) using the economic engineering synthesis technique, suggest that in Californian peach orchards, costs per ton of peaches harvested decrease up to 60 acres of orchard but remain at about the same level thereafter. Michalson (38) applying the synthesis method to arable farms in the Washington-Idaho area concluded that maximum cost efficiency would be obtained at about 1600 acres and that there would then be dis-economies of size up to 1900 acres. Heady, McKee and Heady (18) found that on Iowa farms there should be little cost economy over 320 acres, with possible dis-economies after 1000 acres.

Carter and Dean (36) investigating size economies in California cash crop farms by both survey and synthesis methods (using both budgeting and linear programming), concluded that there are likely to be substantial economies up to about $120,000 output (about 700 acres) further slight economies up to $24,000 output (1420 acres) and slight diseconomies thereafter. Sturrock and Gunn (42) say that an investigation currently being carried out on farms in Britain of over 2000 acres indicates that such farms probably have few technical economies of size which are not available to farms of 500-1000 acres, and also suffer from disadvantages in management control which may produce overall diseconomies of size.

3.04 Heady, McKee and Heady (18) suggest that because of family labour, farms of 160 acres are as viable as those of 320 acres (the size at which they found size economies to level off) and that machinery cost differentials are unlikely to be a final determining factor in farm size pattern. They substantiate this by showing that of five farm types, Cash Grain farms, which might be expected to derive greatest benefit from economies of size due to mechanisation, had in fact showed the smallest reduction in farm numbers from 1920-50, while the Southern Pasture type with little dependence on mechanisation had the greatest degree of consolidation.

<u>% Change in No. of farms over 49 acres, Iowa 1920-50</u>

Cash Grain	-1.8%
N.E. Dairy	-2.9%
W. Livestock	-5.9%
E. Livestock	-7.5%
S. Pasture	-13.1%

Upchurch (28) points out that the common generalisation that unit costs are high on small farms and low on big farms, is vulnerable, and that farm size adjustments are explained by cause-effect relationships other than economies of size. Sturrock and Gunn (42) think it unlikely that all farms will in the future be large, since the small farmer has the advantage of personal attention and lower overheads (for example, they do not have to pay for management).

3.05 While whole farm profit is affected by the cost per unit of output, it is also affected by output per acre. Variation in output per acre as farm size changes may result from variation of management input, or may be a direct result of management choice. Maunder (9) in a survey of 39 farms in S.W. England which had changed their size between 1953 and 1963, found that although in some cases output per acre was greater on the larger acreage farms, the general tendency was opposite to this (see Figure D), but less marked where crop production was important.

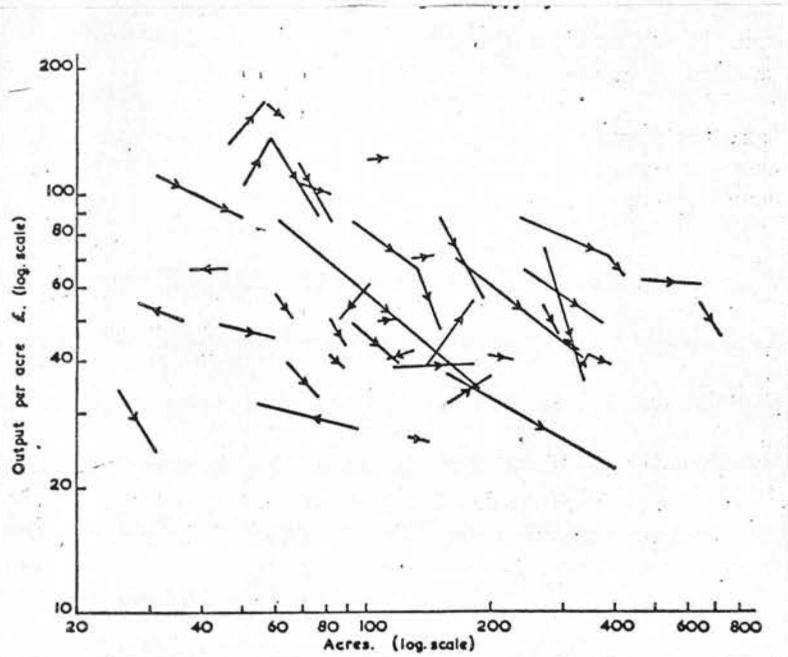


FIGURE D: Changes in acreage and in Output per acre S.W. England 1953-63.

Hoffman and Heady (43) claim that when 115 farms in Iowa absorbed 99 other farms, crop output per acre rose from $38 per acre for the absorbed farms, and $44 per acre for the absorbing farms, to $54 per acre for the amalgamated units. This increase stems from the expectation of the absorbing farmers, that yields of individual crops would be 15% to 28% higher on the amalgamated farms, than on their own farms at present. The weakness is that these apparently were expected increases, not accomplished ones, and there may have been some over-optimism. The average pre-amalgamation crop yields (bushels per acre) quoted for the farms which were absorbed and those which did the absorbing, are shown below together with the crop yields expected from the amalgamated units.

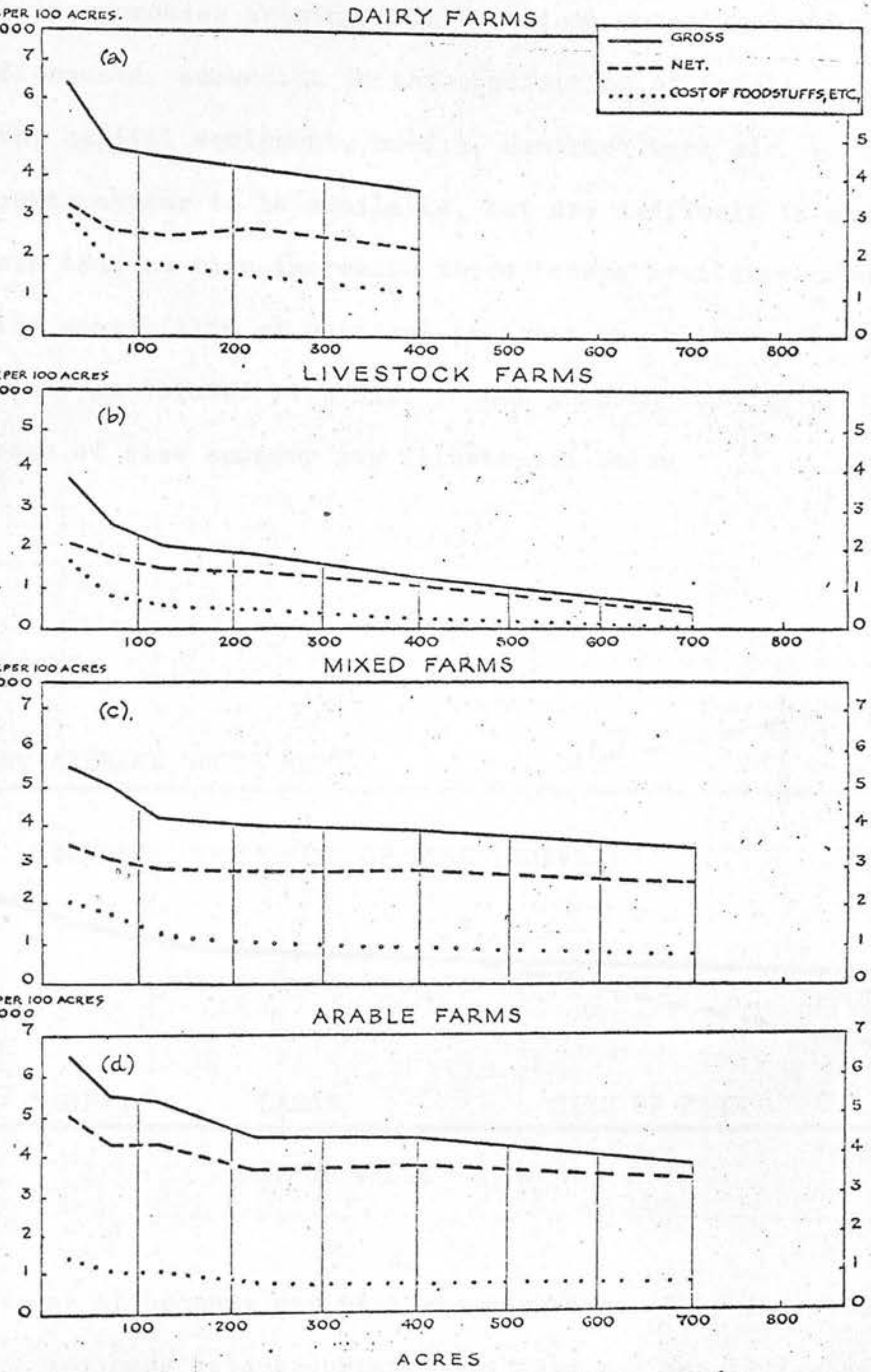
CROP	ABSORBED FARMS	ABSORBING FARMS	AMALGAMATED UNITS
Maize	42.7	48.4	62.2
Sorghum	50.5	48.6	57.4
Oats	29.1	31.8	39.1
Soybeans	20.6	24.7	28.9
Wheat	26.3	31.6	36.2
Silage	45.8	50.3	58.2
Hay (Tons)	2.3	2.9	3.0

Maunder (44) in criticising these results, noted that on 8 farms which increased their size on average from 150 acres to 319 acres between 1949 and 1959, the average output per acre fell from £40 per acre to £34.2 per acre. Sturrock (2) shows Net Output per acre on 200 East Anglian farms grouped according to size, to fall between the 20/50 acre and 50/100 acre groups but to be fairly constant in the 100/150 acre, 150/300 acre, and 300+ acre groups.

ACRES	NET OUTPUT/AC.
20-50	60.1
50-100	43.5
100-150	40.5
150-300	40.8
300+	39.9

Simpson (14) in a survey in Yorkshire showed that farms in each of four type groups increased in both Gross Output per acre and Net Output per acre with greater size of business. Graves and Sturrock (45) found that in two farm types in the Eastern Counties, Gross Output per acre decreased as acreage increased, but that there was no evidence of any difference in Net Output per acre except that the smallest, most intensive group of farms had a higher Net Output. A report by the Natural Resources (Technical) Committee (46) includes data from the Farm Management Survey of England and Wales for 1955-56 which shows, for each of four farming types (Dairy, Livestock, Mixed and Arable), that Gross Output per 100 acres falls fairly rapidly to around 100 acres and continues to fall less rapidly thereafter. Net Output follows the same general pattern, but the changes are less accentuated.

Lower output per farm acre on larger farms need not necessarily indicate lower crop or livestock yields per acre, since there will also be differences in system intensity. Small farms tend to have a high proportion of high output enterprises, while the larger farmer can get a sufficiently high total output to make a living, from enterprises with a low unit output, which cause less management difficulty. Long (13) comments that the fact that profits per acre seem to show little variation on farms of similar type, whatever the size, does not mean that there are no advantages of size, but that the benefits from them are taken in other ways. Larger farmers may invest more in machinery than is necessary, to reduce risk, and for job satisfaction, or they may simply relax their effort when a sufficient income has been reached.

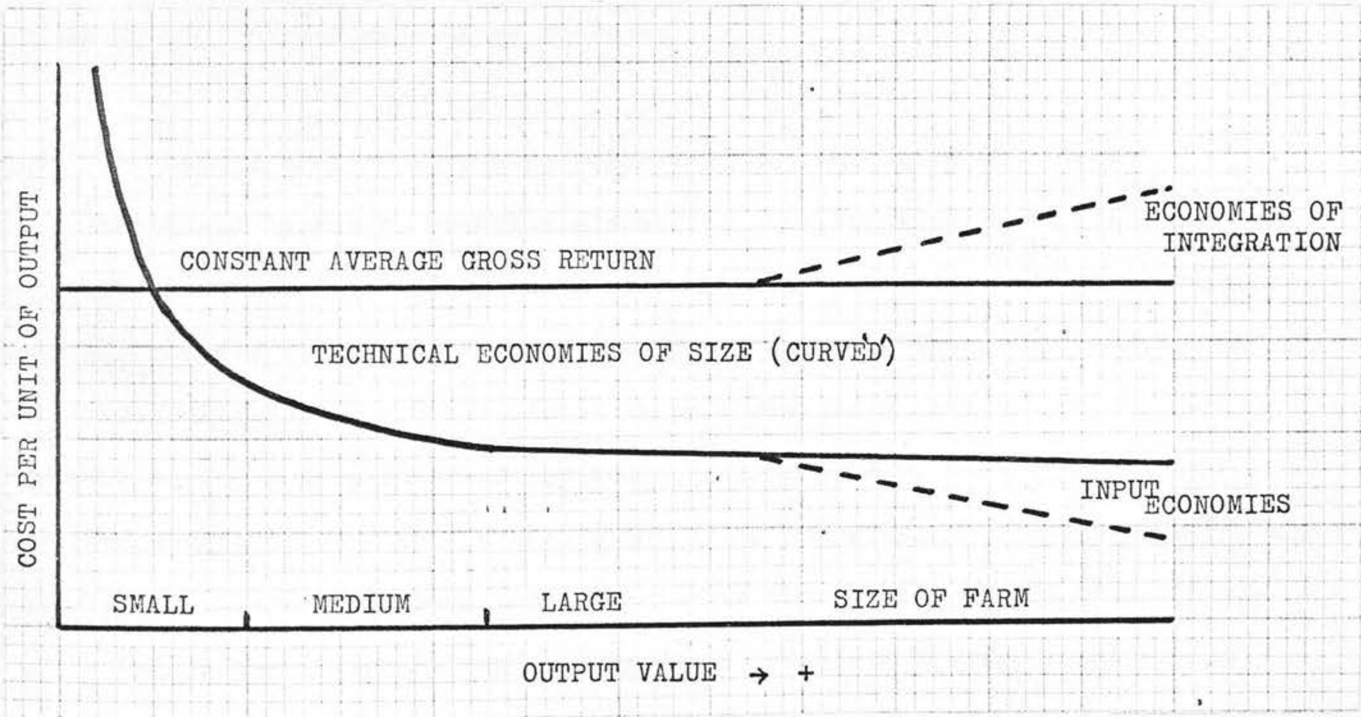


Gross and net output per 100 acres

(F.M.S. sample, England and Wales 1955-56)

4.0 Action Intended to Reduce The Problem of Low Income Farms

4.01 Faris (26) points out that the larger farm business may have, in addition to economies arising from technical relationships such as have been discussed, economies in the acquisition of inputs - annual physical inputs, capital equipment, credit, contract work etc. - for which quantity discounts appear to be available, but are difficult to quantify. He also suggests that as size increases there become available economies arising from the possibility of vertical integration, although he qualifies this as an economy associated with size rather than an economy of size. These three areas of size economy are illustrated below



Each of these areas of economy may be taken advantage of by individuals, if their size of business is appropriate, but they may also be implemented by several farmers acting in unison to achieve benefits which their individual businesses are too small to produce.

4.02 From 1955 to 1960 two movements, similar in context, started within farming, the functionings of which are based on the responsibility of participators towards each other. In 1955, A.R.L. Aylward formed the first machinery syndicate in Hampshire. The idea of sharing machines in order to use them to full capacity, and to allow machines to be used which would be totally uneconomic on one farm, (thus obtaining the technical economies of size mentioned by Faris) was so successful that by 1965 there were about 630 machinery syndicates in England and Wales. Initial fears of self interest among members have proved largely unfounded, and credit facilities for the purchase of machines are administered by the National Farmers' Union. The system is very flexible, many farmers being members of several syndicates, each operating a different machine or machines.

4.03 The second area of advantage related to business size which was mentioned by Faris, quantity discount in the acquisition of inputs, can also be attained by individual farmers but the possibility of the individual exerting commercial pressure may be limited because, as Thomas (47) says, "By comparison with 'Big Business' almost every farmer is a commercial pigmy. Any business having a proportion of its raw materials sold to and its finished products bought by, the same organisation is in no position to trade sensibly or effectively unless it is comparable in size to those with whom it trades."

A fairly small group of moderately sized farms can however considerably exceed a total size (in acres or in volume of trade) which would be considered very large in regard to a single farm. Rys Thomas is credited with starting, in 1958, what is now known as the 'Group Movement'. Groups have been formed for most farm activities, but the essential feature seems to be a fairly small number (say 5-30) of selected members who are prepared to accept some restrictions on individual activity for their mutual benefit. Commonest, and possibly most successful, are buying groups, the members of which combine and rationalise their requirements in order to get more favourable terms for a large homogenous order than could be obtained for several smaller, varied orders. Reduction of the unit cost of inputs may very well be, in the case of farming based on intensive enterprises, the only area in which substantial economies of size are feasible. Juckes (48) concludes that this is the case in pig farming in Britain.

4.04 Marketing groups are more difficult to operate successfully than are buying groups, since selling is a much more sophisticated job than buying, involving an understanding of marketing and business principles. Member loyalty is also more difficult to maintain in the face of rapidly changing market prices. Most marketing groups have been formed on the basis of selling high quality produce, with the supply controlled to match consumer demand. Group marketing does not of itself make high quality produce, and unless prices can at all times be kept above the general market price, members tend to sell outside the group so destroying the second aim of supply control which is itself essential to price improvement.

Reasons given by Barber (49) for the emergence of marketing Groups are (a) The belief that group action is the key to prosperity (b) The belief that 'middlemen' take a large part of the profit (c) Fear of outside interests gaining control of production by vertical integration.

There is some reason for the farming industry to be wary of large animal feed compounders and food retailers who are willing to supply capital and fairly assured prices, but in return require the farmer to obtain inputs from specific sources and to employ particular methods of production. The compounder etc. may then virtually control the farmer's enterprise - in some cases, a large part of his business. Vertical integration is fairly common in the U.S.A., is already well advanced in the British poultry industry and is seen as a possibility in relation to other farm enterprises. The advantages and dangers of this type of contractual arrangement are discussed in a report commissioned by the National Farmers' Union (50).

One reason, however, for the failure of some marketing groups is that they have tried, with too little knowledge and experience, and too few resources, to take their produce further along the marketing chain towards the consumer - doing their own vertical integration by, for example, undertaking slaughtering or packaging. It may be that farmer controlled integration can be better carried out by Agricultural Co-operatives. The Co-operative movement is world wide, is of long standing, and in many countries (Denmark, Germany) is of vital importance to the agricultural industry. In Britain, Co-operatives are currently mainly concerned with trading in fertiliser, feeds, and grain, and have been very similar to large commercial firms operating in the same trade. Their difficulties appear to have been, in the main, lack of member loyalty, and amateur management. This lack of member loyalty - farmers treating the co-operative trading society of which they are members as one more source of feed or outlet for produce - may be engendered by their size leading to a feeling of impersonality, a lack of identification. The size of the co-operative movement may however be an advantage if a regeneration and shift of emphasis is brought about. Some Co-operatives are beginning to perform an integrative function, and if this were extended marketing control could be kept within agriculture. West Cumberland Farmers for example, (51) organise for their members transfers of pigs and calves, have a contract marketing scheme for cereals and potatoes, and are considering the possibility of centralised dressing and grading of potatoes. They have also integrated egg production among their members, providing chicks, feed, housing and advice.

4.05 Production seems to be one of the most viable areas for group activity.

The normal pattern is for members to rent land to the group, on which a chosen crop will be grown under the supervision of one member; crop variety, fertilisation and cultivation methods are agreed to, and machinery is owned by the group. A production group in fact may well have the functions of the three types of group activity already mentioned - requisite purchase, machinery syndication, and the requirements for a successful selling group, all three being improved upon by cropping rationalisation. In a few cases labour is pooled, especially on small farms with housing difficulties - a group of eight farms in Yorkshire, for example, the labour for which is housed in a hostel.(52)

The logical extension to the various group activities, which is taking place in some cases, is towards fuller integration of the businesses. One example of this is at Berwick St. John, Wiltshire (53), where 7 farmers with 2250 acres in a fairly compact block of land ranging from heavy clay to chalk join forces for spring cultivations, harvest, grain drying and storage and livestock grazing, and are intending to integrate their silage making operations. Another example, in which integration has been taken even further, is at Sherborne St. John, in Hampshire (54), where three dairy farmers with a total of 205 acres have formed a partnership, pooling their tenant's capital. They intend to draw wages from the partnership and use profits for expansion, reviewing the situation after five years. Dairying gives another example of almost full amalgamation in Northern Ireland, where Dunlop and Workman (55) report that three farmers have a jointly owned 100 cow unit which leases 50 acres from each of the farms. One point that these groups of farmers stress is that the people involved should be of the same age group and have similar family committments.

4.06 In most Western European countries there is some form of governmental activity aimed at reducing the problem of non-viable farms (3).

Where whole areas are on a low economic plane, regional development may tend to increase farm incomes along with those of the rest of the community. Few countries provide financial assistance specifically for the smaller farmer. In Britain, the Small Farmer Scheme, which was replaced by the Small Farmer (Business Management) Scheme in 1965, provided grants for approved schemes of farm business intensification. In Austria, grants reducing the interest rates on commercial credit are available only for smaller farmers. In the U.S.A. a credit scheme is available to low income farmers who have difficulty in obtaining commercial credit.

Mainly, official activity is aimed at enlarging farms. In countries where fragmentation is the main problem, consolidation may be the primary object, by revision of inheritance laws, financial retirement incentives to older farmers, or government projects aimed at reorganisation of the farms in specific areas. Where amalgamation is the object, government bodies may have powers of compulsory purchase (e.g. Eire, Sweden and Iceland); they may have pre-emptive rights on farms offered for sale (Denmark, France, Germany, Norway); or they may have to compete for land in the open market. In some countries no direct action is taken to enlarge farms, but grants are available to assist in the cost of private schemes. (Eire, France, Britain), and elderly farmers on small farms may be tempted to give up their land by special pensions (Germany, France, Netherlands, Austria, Eire, Britain). In Sweden for example, Wetterhall (19) records that Agricultural Boards have the power to buy land for resale to selected farmers in order to increase the size of their holdings. Before any person can buy land they must obtain governmental permission, which is normally refused to foundations, joint stock companies etc., and may be refused to an individual if the land could better be used to enlarge a neighbouring farm. Grants are available to cover the costs (legal etc.) of ownership transfer and grants and government guaranteed long term loans are available to help with structural and internal improvements.

4.07 The 'small farm problem' in Britain has caused a considerable amount of official concern and several governmental aid schemes have been aimed specifically at overcoming it. Sturrock (2) suggests that there are three possible solutions (a) Raising farm produce prices to such a level that the small farm can make a reasonable profit. This would be very expensive to the nation since it would not be possible to concentrate the extra income on small farms only (b) Encourage the small farmer to enlarge his business by intensification without increasing acreage. This might be limited in its full effect by the market for pigs, poultry, vegetables and fruit. (c) Encourage amalgamation, since the small farmer's basic shortcoming is difficulty in fully utilising equipment, making him overcapitalised and labour inefficient.

The 'Small Farmer Scheme' was introduced in 1959 to provide grants of up to £1000 over a period of several years for approved schemes of business expansion linked to acceptable husbandry techniques - an encouragement to intensify, the second of Sturrock's possible solutions. In 1961 the Natural Resources (Technical) Committee commented in a report that "Any extra help which might be given (to small farmers) on social grounds should be consistent with the national interest, which requires that the pattern of agriculture should be flexible enough to meet changing economic circumstances. Such help, if contemplated in the future, should not include differential income subsidies or other means of propping-up non-viable units, but might more profitably take the form of assisting those who wish to move out of agriculture "and also "Whether or not measures should be taken to provide inducements towards amalgamation is an open question."

In 1967 steps were taken to encourage an increase in the size of farms (the third of Sturrock's possibilities) by the introduction of the 'Farm Amalgamations and Boundary Adjustments Scheme" and the 'Farm Structure (Payment to Outgoers) Scheme.' The first of these makes available grants of 50% of the cost of buildings, houses, roads, demolition and legal work etc., required to carry out an approved scheme of farm amalgamation and also provides for loans towards other costs of up to 90% (100% for certain small amalgamations) of the valuation (by the Agricultural Mortgage Corporation or the Scottish Agricultural Securities Corporation) of the combined unit after amalgamation. Normally, it is required that at least one holding of less than 600 Standard Man Days be involved in the amalgamation and that the resulting farm business shall exceed 600 S.M.D. An exception can be made where it is not possible to complete the amalgamation in one stage. In this case the first stage must produce a holding of at least 275 S.M.D., Boundary alterations by exchange of land to reduce fragmentation are also eligible for grant under this scheme. It is a condition of this grant that units so formed must remain in farming for 40 years and must not be split up again.

The Farm Structure (Payment ot Outgoers) Scheme supplements the Amalgamation Scheme by making available lump sum payments or annuities to encourage the occupiers of uneconomic holdings to vacate them so that amalgamation can proceed. The type and amount of payment depends on the age and circumstances of the outgoer, only those who were occupying the holding at 31st October, 1967 (or their heirs), being eligible and also if the income of an outgoer and his wife, from sources other than the farm, exceeds £400 per annum, they must in order to qualify for grant, earn £3 from the farm for every £1 by which their external income exceeds £400. There are three categories of grant.

(a) Up to age 55 years: A lump sum payment for holdings of up to 10 acres, plus an additional £10 per acre for each acre in excess of 10 acres, but subject to a maximum of £2000.

(b) Over age 65 years: An annuity of £200 for holdings of up to 10 acres, plus an additional £0-75 per acre for each acre in excess of 10 acres, but subject to a maximum of £275.

(c) Age 55 years to 65 years: The option of choosing either (a) or (b).

The Agricultural Adjustment Unit, Newcastle, has attempted (40) to estimate the possible effect of these two grant schemes. They suggest that projections of past trends in the reduction of farm numbers incorporating the recent acceleration in pace of change show a probable decline of 14% from 1967 to 1973. Calculations of response to the Amalgamation and Payment to Outgoers grants suggest a 14%-28% reduction in numbers due to these grants. Combining the two projections and allowing for overlap gives a suggested range of 20%-35% in the number of farms in existence in 1967 which will have disappeared by 1973.

Also in 1967 the 'Agricultural and Horticultural Co-operation Scheme' was introduced to encourage the development of larger business units to which would accrue some economies of size, without reducing the number of farmers. To this end grants were made available under several headings, towards the cost of establishing agricultural or horticultural business ventures (including marketing) in which three or more separate farmers are involved. These grants are administered by the Central Council for Agricultural and Horticultural Co-operation and make available the following:

(a) Up to 75 per cent of the cost of research by co-operative associations or other bodies which, although likely to be of benefit to the applicant, also promises to be of wider benefit to co-operation generally;

(b) Up to 75 per cent of the cost of setting up a co-operative association, including preliminary studies and surveys, legal and accountancy fees, registration fees and certain other expenses;

(c) Up to $33\frac{1}{3}$ per cent of the cost of salaries and expenses for the initial employment (for up to 3 years) of managerial and other key staff by co-operative associations;

(d) Up to 75 per cent of the cost of training or refresher training for managerial and other key staff of co-operative associations.

(e) Up to 75 per cent of the cost of surveys and studies to improve efficiency and/or assess the feasibility of possible activities for co-operative associations.

(f) Up to $33\frac{1}{3}$ per cent of the cost of constructing, enlarging or adapting buildings and fixed equipment for co-operative associations, where these are required to provide new or additional facilities, greater capacity or improved methods of operation;

(g) Up to $33\frac{1}{3}$ per cent of the estimated expense in connection with the initial operation, the expansion, or increasing the efficiency of co-operative associations. This 'working capital' may include capital items not specifically grant-aided elsewhere under the Scheme and operating costs or an increase in operating costs during a limited initial period;

(h) Up to $33\frac{1}{3}$ per cent of the cost of building and equipping horticultural producers' co-operative wholesale markets in production areas;

(i) Grants, unrelated to any specific costs or expenses, may be made to individual small producers who submit a joint proposal which displays a genuine endeavour to co-operate in one or more substantial respects and which seeks collective improvements in productivity or marketing. Proposals will be considered from farmers and growers whose production businesses meet the conditions of eligibility of the current schemes for small producers under the Agriculture (Small Farmers) Act, 1959, or the Agriculture and Horticulture Act, 1964, irrespective of whether they have completed or are currently undertaking a programme under those schemes or have never applied for grant under them. The amount of grant payable to each participant in a joint proposal will be up to one-third of the amount of grant applicable to him in respect of a successful application under the relevant Scheme for small producers.

In addition to this range of grants, the Council has power to make grants of up to 90 per cent of the cost of (1) desirable research where there are no spontaneous proposals and, at the Council's initiation, a person or body sponsors the work and (2), exceptionally, the setting up and the first three years' activities of co-operative associations engaging in new fields of co-operation, normally in respect of production activities but exceptionally in respect of marketing.

As stated, the scheme provides for a grant of up to 75% of the cost of studies of the economic and physical and constitutional feasibility of proposed schemes, and the Central Council strongly recommend that proposed schemes should be subjected to such detailed studies. As Ewing (55) says, "A pre-requisite to participation in group production activities is an examination of current farm resources and financial situation. These in turn must be weighed against the potential of the group venture. It is perhaps appropriate at this point to state that this preliminary appraisal has not been a factor of all group development".

4.08 There is little evidence of previous research directed specifically at discovering the probable result of the amalgamation of several farms into one integrated business unit.

Dixey and Maunder (30) selected three typical farms (small, medium and large) in an area of 3382 acres containing 10 small (c. 30 acre) farms, 12 medium (c. 140 acres) farms and 5 large (c. 300 acre) farms. They then calculated, using standardised physical input-output data and prices, applied to the actual farming systems, the outputs inputs and profits obtained from each of the three farms. The three farms were then replanned by budgeting, using the same standardised data (i.e. the economic - engineering synthesis approach). Approximate Average Cost curves were drawn for each of the three farm sizes, and connected by a tangential curve to indicate the size of farm having the greatest economic efficiency.

They concluded that farms of about 300 acres had the lowest unit costs of output, and defined boundary alterations and buildings required to produce 11 farms of about this size in the area. The expected profit from these farms was then compared to that from the existing 27 farms, as shown below, in total. It is notable that the profit improvement derives much more from reduced costs, than from increased output.

	PRESENT	PLANNED	CHANGE	%
Milk Sales	76631	85412	+8781	+11.5
Other receipts	78882	50818	-8064	-13.7
TOTAL OUTPUT	135,513	136,230	+ 717	+ 0.5
Labour (inc. farmers)	36095	32062	-4033	-11.2
Feed	28004	24077	-3927	-14.0
Fertiliser	15113	16036	+ 923	+ 6.1
Tenants Capital (Int.+ Depr.)	17898	18298	+ 400	+ 2.2
Other expenditure	30286	27919	-2367	- 7.8
TOTAL COSTS	127,396	118,392	-9004	- 7.1
PROFIT	8117	17838	+9721	+119.8

Sturrock (56) investigated the possible advantages of amalgamating County Council smallholdings by using linear programming to calculate the income that could be produced by a family from various acreages. Three sizes of family (1, $1\frac{1}{2}$ and 2 adults) were assumed and these labour constraints were applied to acreages ranging from 30 to 200 (Two sets of standard labour coefficients were used - Small Farm for 30-100 acres and Medium Farm for 100-200 acres). Sturrock's results indicate that the optimum holding sizes for the three family sizes were: 1 adult - approx. 100 acres; $1\frac{1}{2}$ adults - approx. 150 acres; 2 adults - approx. 200 acres+.

FAMILY INCOMES PER HOLDING

	Small Farm Standard				Med. Farm Standards			
Acres:	30	50	70	100	100	120	150	200
Family	£	£	£	£	£	£	£	£
1	492	989	1403	1843	1589	1467	1014	260
$1\frac{1}{2}$	492	1010	1516	2143	2124	2364	2525	2028
2	492	1010	1528	2265	2301	2751	3137	3464

There have been several reports on multiple farm amalgamations which have taken place on agricultural estates. For example the Vaynol Estate - 400 farms on 22,000 acres consolidated to 128 farms (Jones and Jones (23)); the Inverernie Estate - 8 farms amalgamated to produce one, with an increase in arable land, in stock carried and in community viability (Grisewood (25)); the Cadlands Estate - three farms with total of 738 acres amalgamated with a labour reduction of 9 people (from 17 to 8) at a saving of £2661 (£8061 to £5400). Machinery investment and running costs were cut, respectively, from £9356 to £8700 and from £5447 to £4200 (Whitlock (57)).

4.09 The problem to which this thesis relates is to examine six specific farms and to determine as far as possible changes in the utilisation of, and net income from, the constituent area of 2811 acres, concomitant upon the amalgamation of the six farms.

Therefore, although 'economies of size' will very probably have a considerable effect on the comparative financial result due to an increased acreage allowing more chance of full utilisation, and therefore minimal cost per unit output, of equipment etc., the problem is not the fairly simple one of defining an optimum acreage for (e.g.) a machine or group of machines, or for the type of machines currently available on the market but rather of defining an optimum group of machines for a given task or probably a more complex problem still - that of arriving at the optimum combination of two variables, the quantity of machinery (of various types) and the amount of work they shall do.

A possible approach to planning the utilisation of a 2811 acre farm would be that used by Mitchell (58). In this case a group of farmers were asked to discuss and define, in the course of a series of meetings, the alterations to their initial total machinery complement and labour force which would be made possible if their farms were run co-operatively.

It seemed probable that the present study, involving not only re-organisation of labour and machinery but also a concurrent reorganisation of cropping and stock policy, which would also have to take account of a variety of limiting factors, would require a fairly exhaustive search of the possible organisational patterns, Although this could be tackled by Mitchell's method backed up by a checking and fault-finding procedure, it was considered that the same procedure could be carried out more rigourously by using linear programming, provided that the problem could be mathematically defined with sufficient precision to produce a 'sensible' solution.

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PART TWO

I N V E S T I G A T I O N

INVESTIGATION

5.0 The problem to be studied

5.01 The type of organisation to be investigated is that in which several neighbouring farmers combine their businesses to form one fully integrated unit, with no recognition of the previous existence of separate farms, other than that each man shall retain the ownership of his land, and shall be paid for the use of it. Unless they voluntarily retire, the farmers shall continue to be active in the business of farming, and their heirs shall, if they wish, have as much right and opportunity to follow their parent into farming as they would have had if no amalgamation had taken place.

5.02 It was decided to investigate co-operative farm amalgamation rather than agricultural take-over, for four reasons:

(a) It appears to be the logical extension of, and could develop from the combination of, the various forms of group activity evident in farming since the mid 1950's.

(b) There are problems particular to this type of development. (e.g. Allocation and acceptance of responsibility; profit distribution; transference of heritable property).

(c) Possibly because of these problems, or possibly because this stage has not had time to develop, there are very few examples of this as yet. Only one report (1) of the merging of businesses was found, and the 'Report on Group Development in Agriculture' (2) says "In its extreme form (and there are no more than a handful of examples) co-operation at the farm level expresses itself in a form of co-operation between men with compatible farms - and compatible personalities - which comes very close to complete amalgamation." (Page 3) and " . . . there are very few examples of farmers who set out to plan their farming enterprises together from start to finish, and to organise themselves as a single farm". (Page 22).

(d) There tends to be a body of opinion which accepts on principle that co-operative action must be advantageous financially, if not socially, and it was felt that this could lead to possibly ill-considered action*

5.03 In view of the scarcity of existing amalgamated units formed by voluntary action, it was decided that the investigation should be based on a simulation or feasibility study, rather than on a survey.

The study is based on arable farms of about 400 - 500 acres. It could be considered to be more pertinent to current structural problems in agriculture to utilise farms of 100 - 120 acres, but the larger farm type was selected for two reasons:

(a) It was felt that the medium-large farm, fairly heavily mechanised, and run as a one man business using hired labour, may be more vulnerable in times of agricultural recession than the family farm, where labour does not have to be paid for at statutory rates.

(b) The farmers involved were chosen partly because of their suitability for the kind of participation required of them.

* Since the commencement of this study, the Agricultural and Horticultural Co-operation Scheme has come into force. This, very laudably, requires a full and careful investigation into the feasibility of each proposed scheme of inter-farm co-operation, before grant aid is given.

6.0 General description of the area and of the farms

6.01 Six arable farms in East Lothian ranging from 297 acres to 626 acres (average size of 468.5 acres) were chosen. They are not completely contiguous, although the boundaries of three adjoin. For the purpose of the study they have been treated as though together they formed one complete block of land. The farms and the area in which they lie, are described in Sections 7.0 and 6.03.

The six farmers range in age from about 30 years to 65 years and have a variety of background experience which might be expected to affect their reactions to various suggestions and proposals. Four had been brought up to farming; two had business experience outwith farming; two had university degrees; three had administrative experience outwith farming; all were well educated and highly intelligent men.

6.02 The location of the six farms in relation to East Lothian, and Scotland, is shown in Figure E.

Figure F shows the general geographical and rainfall characteristics of the area, with five of the farms lying on the coastal plain below 250 ft. From the isoclines superimposed on the map it is seen that these five farms lie in an area with an annual average rainfall of 25-26". In Figure G, the seasonal distribution of rainfall (35 year average) is plotted against the seasonal transpiration/evaporation rates for the area (3), showing the potential soil moisture deficit. Another meteorological factor affecting the agricultural potential of the area is the length of growing season, which is measured as the number of days with a mean temperature above 42°F. At North Berwick on the north coastal boundary of the area, the average growing season is 251 days, and

FIGURE E

FIGURE E: Location of farms within E. Lothian and Scotland.

FIGURE F

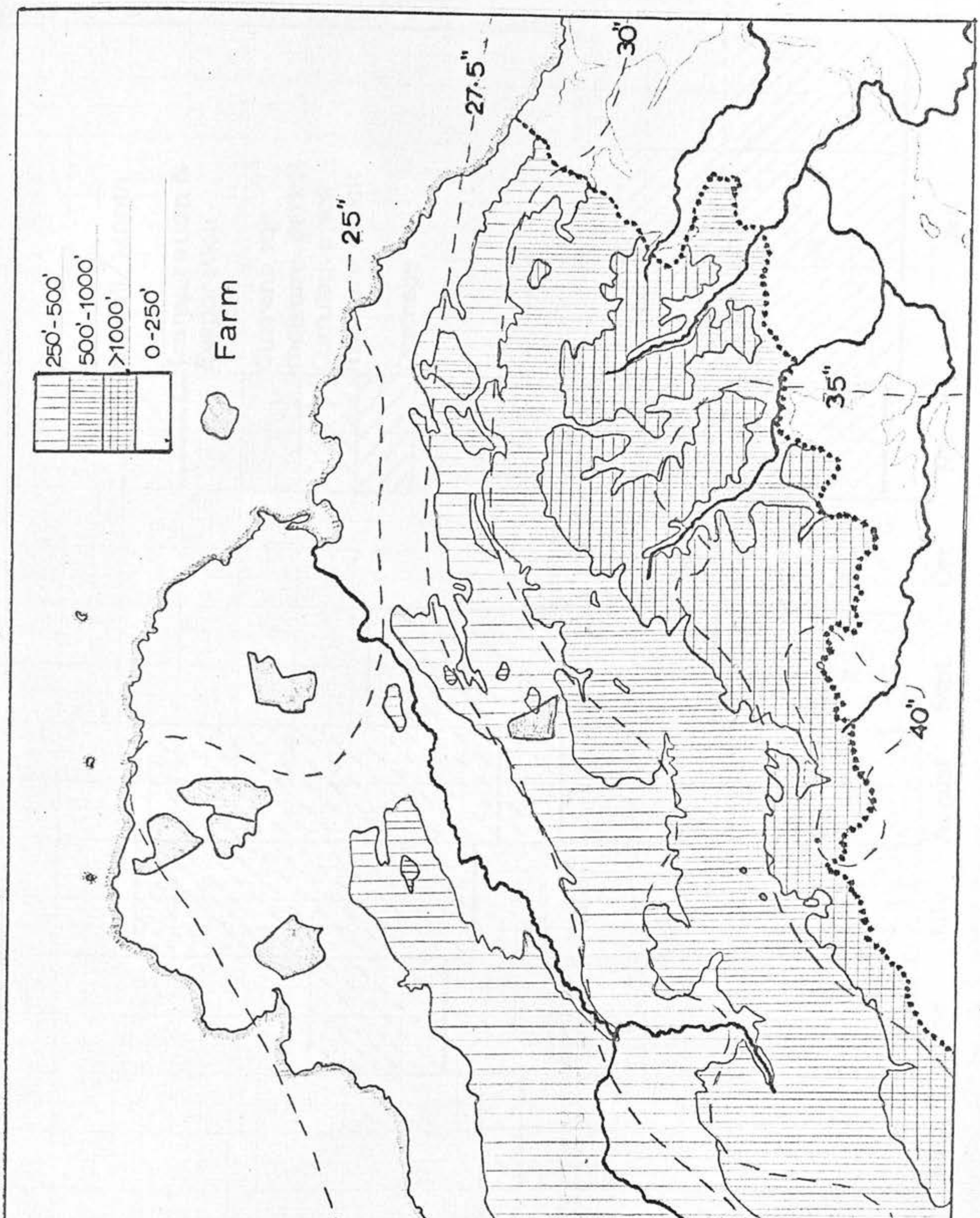
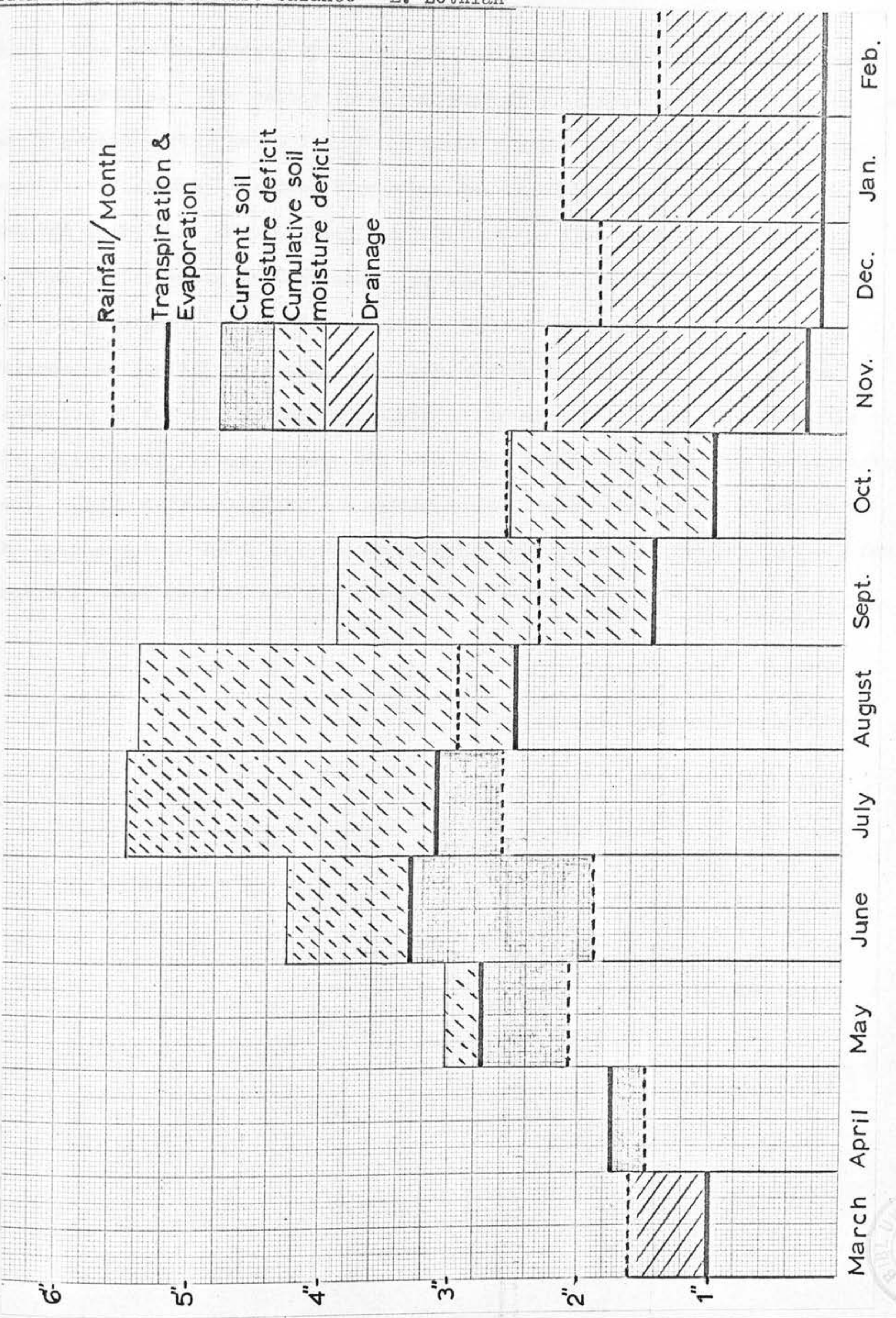


FIGURE F: Relief and Isocline map of part of E. Lothian

FIGURE G

FIGURE G: Soil moisture balance - E. Lothian



at Haddington, in the south but at 250 feet, 234 days.

6.03 The common farming system in East Lothian is based on cash roots and cereals. The better farms can compete with south-west Scotland in the early potato market and with Fife in growing sugar beet, although the south-west is affected by the Gulf Stream and the nearest sugar beet factory is located in Fife. East Lothian and Berwickshire also produce most of the malting barley grown in Scotland. In the past, heavy cattle were fattened to provide organic manure for potatoes, and although this alone is not now regarded as sufficient reason, the main livestock enterprise is still the fattening of forward stores over winter. Several farms also fatten cattle on the barley beef system, a very few have dairy herds, and sheep are occasionally kept, mainly as scavengers. A comparison of the percentage distribution of the main crops in 1965, and the approximate average yield levels attained, for Scotland, East Lothian and the average for the six farms, is given in Table 2.

TABLE 2

	SCOTLAND*		EAST LOTHIAN*		THE SIX FARMS	
	% of Acres	App. Yield	% of Acres	App.** Yield	% of Acres	Yield
Pot. 1st Early	0.4	7.00	0.9	6.40	2.2	7.00
Pot. 2nd Early + Maincrop	2.9	8.70	6.3	10.10	16.1	10.56
Sugar Beet	0.2	11.30	0.8	10.40	3.5	14.00
Wheat	2.3	1.57	13.0	1.79	27.3	2.00
Barley	13.0	1.43	29.0	1.60	38.8	1.80
Oats	10.1	1.04	3.8	1.23	-	-
Stockfeed Roots	5.5	19.94	4.8	21.40	0.7	20.00
Temp.Grass Cut	15.3	1.84	8.2	1.88	5.6	2.75
" " Grazed	28.7		18.3		2.3	
Oth. Arab. Crops	0.9		3.7		0.7	
Total Arable	79.3		88.7		97.2	
Permanent Grass	20.7		11.2		2.8	
Av.Farm Size	75.7		176.7		468.5	

TABLE 2: PERCENTAGE DISTRIBUTION OF MAIN CROPS (EXCLUDING ROUGH GRAZING) 1965 AND APPROXIMATE AVERAGE YIELDS IN TONS (1960-64)

** Yields quoted are for South East Scotland (Berwick, E. Lothian, Midlothian, W. Lothian, Peebles, Roxburgh and Selkirk), as yield recording by counties has been discontinued.

* Agricultural Statistics 1965 Scotland; Dept. of Agric. and Fisheries for Scotland.

7.0 Particular Description of the Farms

7.01 The six farms involved in the study totalled 2811 acres of arable land, plus 80 acres which were in permanent grass because of surface rock, steep ground, or wetness. The twelve soil types found on the farms are listed and described in Appendix A, but for convenience of comparison, and to align with the farmers' interpretations of their land, these are condensed into five broad categories: Heavy, Medium-Heavy, Medium, Light and Thin. There is some overlapping, since for example, Kilmarnock soil series can range from stiff, heavy clay to fairly easily worked clay loam. Table 3 shows the distribution of the soils described in Appendix A, within the five categories mentioned above, and the maps in Figure H show the distribution on the farms of the soil types in Appendix A.

TABLE 3

Heavy	:	Kilmarnock(KK); Peffer(PF); Humbie(HM); Alluvium(AL)
Med-Heavy	:	Kilmarnock; Winton(WN); Alluvium; Cauldside(CU); Smailham(SM)
Medium	:	Kilmarnock; Dreghorn(DR); Peffer; Brownrig(BG)
Light	:	Fraserburgh(FR); Macmerry(MY)
Thin	:	Darleith (DLb,DLt)

TABLE 3: SOIL TYPES IN FIVE LAND CATEGORIES

7.02 Besides having land made up of various combinations and areas of these five soil categories, the six farms also differ in the amount of crop storage space, livestock housing, and irrigation water available. They vary in elevation and aspect. Table 4 lists this information for each of the farms.

FIGURE H

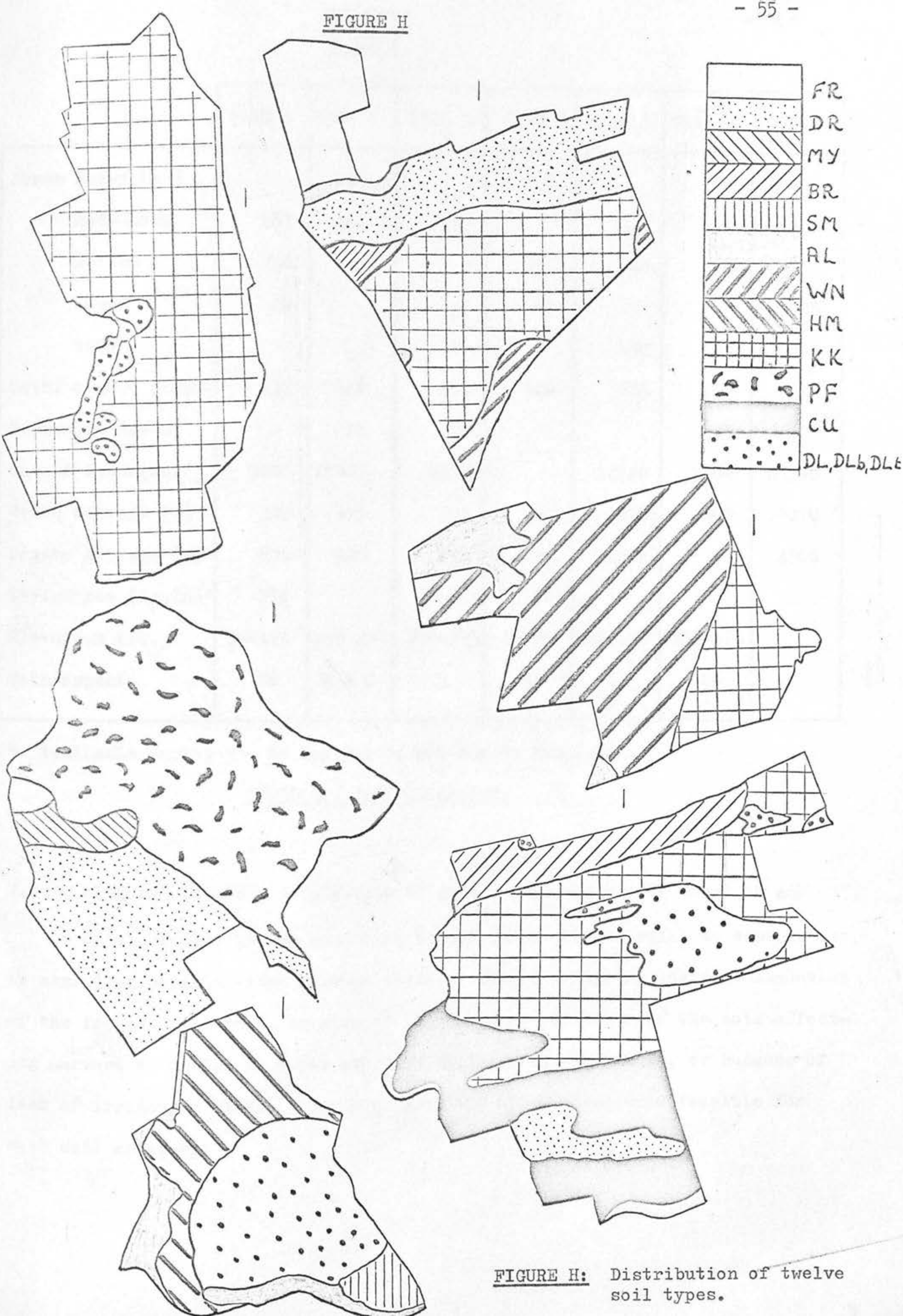


FIGURE H: Distribution of twelve soil types.

TABLE 4

	FARM 1	FARM 2	FARM 3	FARM 4	FARM 5	FARM 6	GROUP
Acres Heavy Land		181		140		122	443
Med-Heavy	183	361	403		366	20	1333
Medium	220			275	160		655
Light	40			85			125
Thin					100	155	255
Total arable acres	443	542	403	500	625	297	2811
Permanent Grass		12	20			45	77
Cattle Space(Sq.')	9600	15600	3450		12740	5000	46390
Grain Storage (T)	300	300	700	500	270)	500	2070
Potato Storage (T)	800	900	700	400	1000)		4300
Irrigation (Ac.In)*	210			720			
Elevation (ft.)	25-125	195-250	100-225	25-50	50-150	300-575	
Main Aspect	NW	N & S	W	NW	S	NW	

* Available during the 60 day period mid-May to Mid-July.

TABLE 4: FARM PARAMETERS

7.03 Although it would be possible to grow a wide variety of crops on any of the soils, it was expedient to pre-judge the situation to some extent, by excluding certain crops on some soils. This was done on the recommendation of the farmers concerned, because of heaviness or stoniness of the soil affecting harvest or making an early start to spring work impossible, or because of lack of irrigation water. Table 5 lists the crops considered feasible for each soil category.

TABLE 5

	Heavy	Med-Heavy	Medium	Light	Thin
Maincrop Potatoes	x	x	x	x	x
Early Maincrop	Too late	x	x	x	Too late
2nd Early Potatoes	Too late	Too late	x	x	No water
1st Early Potatoes	Too late	Too late	x	x	No water
Sugar Beet	Too sticky	x	x	x	Too stony
Wheat	x	x	x	x	x
Barley	x	x	x	x	x
Grass	x	x	x	x	x
Irrigated Grazing	x	x	x	x	No water
Swedes	Too sticky	x	x	Too dry	Too stony
Cabbages	x	x	x	x	x

TABLE 5: FEASIBLE CROPS ON FIVE SOIL CATEGORIES

Two of these crops, irrigated grazing and cabbages, are additions to the normal cropping on these farms. Irrigated grazing was included (for dairy cows only) since drought in mid-summer tends to make grazing unreliable, and cabbages were added as an additional cash crop which would allow weed control and would be less vulnerable to wet soil at harvest than sub surface root crop.

Two of the soil categories, 'Light' and 'Thin' each occur on two farms (see Table 4) and vary somewhat. On Farm 4, Light soil is capable of growing all the crops noted in Table 5, but on Farm 1 is not suitable for any root crop because of poor drainage, although it grows similar cereal crops to the light land on Farm 4. Thin land on Farm 5 has more rock outcrop than that on Farm 6, and is considered unsuitable for root harvesting machinery.

Nine livestock enterprises were considered:

(1) Forward stores fattened in Winter.

(2) Stores fattened on grass.

(3) Barley-beef bedded with straw.

(4) Barley-beef kept on slats.

(5) Autumn born calves sold fat at 18 months of age.

(6) Breeding ewes with lambs sold fat.

(7) Dairy cows housed in byres and fed a mixed diet.

(8) Dairy cows housed in yards and fed mainly on silage.

(9) Store pigs fattened in cattle courts during the summer.

The two dairy enterprises and the pigs are additions to the present range of livestock, although pigs have been kept previously on one farm, on a different system.

8.0 The General Approach to the Problem

8.01 The intention of this study is to discover whether the voluntary, co-operative amalgamation of farm businesses is feasible. This question might be answered according to several criteria, but of first importance is "Does it pay"? In order to resolve this, a comparison of 'before' and 'after' must be made. This raises some problems, since the current profitability of the farms is confused by an annual variation in crop yield, constantly changing policy and techniques, and occasional disasters, such as high winds at harvest time stripping a barley crop. The validity of any conclusions drawn from the study will depend on the accuracy with which the performance of the amalgamated unit can be calculated, and upon the confidence with which this can be compared to the original performance of the constituent farms.

8.02 The method used to rationalise the present performance of the six farms is similar to that employed by Dixey and Maunder (4). Standard input-output data for yields on each soil category, prices, labour and capital requirements etc., were calculated and applied to the combination of crops and stock normal to each farm at the start of the study. The standard data were derived from information obtained from the farmers concerned (see Section 9.01). This approach, while overcoming the problem of random vagaries in performance, also assumes that an equal level of competence in production management is achieved by all of the farmers.

There are two other reasons for using this method:

(a) A set of standard data is required when calculating the performance of the amalgamated farm and if six individual sets of data were used to calculate present farm profits, there could be doubts as to the reliability of the comparison, which would depend upon the validity of each set of data.

(b) It is possible that profits calculated at some stage of the comparison may seem unrealistic. If the same, or similar, data is used throughout then this may be the case, without invalidating the comparability of results for different stages, by the criticism of varying optimism or pessimism in the assessment of input-output data.

8.03 Planning the use of the whole 2811 acre unit has difficulties, due to the large number of possible activities, and the complexity and number of the inter-relationships involved. Although it might be possible to solve a problem of this size by reiterative partial budgeting, linear programming was considered to be the most suitable technique to use. The problems involved in building a linear programming model which describes fairly fully the decision making environment, are dealt with in Section 10.0.

Since linear programming gives the maximum profit plan, it may be considered inconclusive to compare the profit from the 2811 acre unit, calculated by linear programming, with the sum of the profits of the component farms in the 2811 acres, when those farm profits may, or may not, be the maxima. Therefore, although profits below the maxima may be due to less than perfect organisational ability in the farmers, a maximum profit plan is calculated for each farm, using the standard input-output data.

As mentioned in Section 7.02, the possibility of introducing dairy cows was considered. The farmers involved subsequently decided that this type of enterprise was not acceptable to them, and it was not included in later calculations. In view of the financial benefit obtained by including dairying in the earlier calculations, it is thought useful to include these results in the comparisons.

8.04 The availability of capital is a question of some difficulty, the basis of the problem being the assurances given by the farmers that in their circumstances, they could individually obtain money fairly readily, if required for financially sound purposes. Such bankers as were consulted gave the impression that capital would not be difficult to obtain for a 2800 acre arable farm with six able farmers involved. It was therefore decided not to limit capital supply when calculating either the individual maximum profit plans, or the plan for the amalgamated unit. For four of the farms, however, the optimal plans used much more capital than used at present, although this may have been due to larger numbers of relatively high risk livestock in the optimal plans. Because of this, an additional set of optimal individual farm plans was prepared, with capital limited in each case to the amount calculated as being required at present.

8.05 Thus the several sets of results calculated for comparison are:

(a) <u>Stage 1</u> The profit, capital requirement and labour force for each farm derived by applying standard input-output data to the present cropping and stocking.

(b) <u>Stage 11</u> The optimal organisation of, and profit from each farm, when there is no limit on capital availability and dairying is not a feasible enterprise.

(c) As (b), but with the supply of capital limited to the amount calculated as required for the present organisation (a).

(d) As (b) but including dairying as a feasible enterprise.

(e) Stage 111 The optimal organisation and profit from the combined unit of 2811 acres, assuming that machine types and rates of work are the same as those on the individual farms, that there is no limit on capital supply, and that dairying is not feasible.

(f) As (e), but including dairying as a feasible enterprise.

(g) Stage IV The altered profit, capital requirement and labour force required if very large machines replace those previously used, in dealing with the cropping programme calculated in (e).

9.0 The derivation of Data

9.01 The individual farm calculations, and also the planning of the amalgamated unit, were based on standard input-output data, much of which was prepared from information obtained from the six farmers by interview. Gathering this information involved two or three visits to each farm at the start of the study and several more at later stages. After each visit information obtained was checked for inconsistencies, and any found were investigated at the next visit. The data were also checked against independent sources wherever possible.

Data were recorded of crop yields from the various soil categories, produce prices at different times of the year; crop inputs of seed, fertiliser, sprays, casual labour etc., and the unit cost of these; costs of, and revenue from live-stock; livestock inputs of concentrates, veterinary services and medicine, haulage, etc.; general performance of livestock and requirements for farm resources, such as accommodation and grazing; techniques of cultivation, crop handling and livestock care, with the associated times and numbers of men required; rotational requirements and restrictions imposed by disease control or soil type.

9.02 The information gathered from the six farms was then compared, and taking the farmers' comments into consideration, standard input-output data were evolved. For example, <u>Table 6</u> shows the yields quoted for the various crops grown on the five soil categories, and the standard yields derived from these.

The labour requirements of the various enterprises are given in <u>Appendix B</u>, with discussion of the problem of work planning in Section 15.0. The composition of enterprise margins and costs is given in <u>Appendix C</u>. Data relating to machinery were based on the types of implements in common use on the farms,

TABLE 6

	F.1	F.2	F.3	F.4	F.5	F.6	STANDARD
Heavy Soil							
M.C. Potatoes		10½T		10T		–	10T
Wheat		45c		40c		41c	42c
Barley		40c		34c		36c	37c
Med-Heavy Soil							
M.C. Potatoes	11½T	11T	11T		11T	10T	11T
E.M.C. Potatoes	11T	–	–		11T	–	11T
Sugar Beet	12T	11T	–		12T	–	12T
Wheat	43c	45c	42c		40c	40c	42c
Barley	42c	40c	37c		36c	36c	37½c
Medium Soil							
M.C. Potatoes	13T			13T	11T		12T
E.M.C. Potatoes	12T			12T	12T		12T
1st Early "	7T			7T	–		7T
2nd Early "	9T			10T	–		9T
Sugar Beet	15T			13T	13T		14T
Wheat	42C			36c	40c		40c
Barley	41C			34c	36c		37c
Light Soil							
M.C. Potatoes	–			10T			10T
E.M.C. "	–			10T			10T
1st Early "	–			7T			7T
2nd Early "	–			9T			9T
Sugar Beet	–			12T			12T
Wheat	32c			32c			32c
Barley	30c			30c			30c
Thin Soil							
M.C. Potatoes					–	8T	8T
Wheat					32c	32c	32c
Barley					28c	28c	28c

* Yields of potatoes are gross weight, including brock etc.

Cereal yields are dried weight. T = Tons c = cwt.

TABLE 6: QUOTED CROP YIELDS AND DERIVED STANDARD YIELDS*

prices of new machines being obtained from dealers, and repair and depreciation charges derived by the methods suggested by Culpin (5). The tables from which these costs were calculated are shown in Figure I and Table 7. Further reference to this is made in Section 16.0, and machinery prices are listed in Appendix D.

Capital is taken to refer only to the tenants' capital required for livestock and equipment, and to balance any excess of cumulative expenditure over cumulative income during the year. Requirements can therefore be mainly derived from the gross margin data. The inclusion of capital in the planning model is discussed in Section 14.0, and the capital requirements of the various activities are detailed in Appendix E.

		Annual Use (Hours)			
		1-50	51-100	101-200	201+
		%	%	%	%
GROUP I Plough: Cultivators; Toothed Harrows; Hoes; Elevator Potato Diggers; Potato Harvesters	Normal Soils	.09	.08	.07	.07
	Abrasive Soils	.12	.11	.10	.10
GROUP II Rotary Cultivators; Mowers, Binders; Pea Cutter-Windrowers; Ridgers		.08	.07	.06	.06
GROUP III Disc Harrows; Fert.dists.; F.Y.M. Spreaders; Combine Drills; Potato Planters with Fertiliser Attachment; Sprayers; Hedge Cutting Machines; Sugar Beet Harvs.		.06	.05	.05	.05
GROUP IV Swath turners; Tedders; Side Delivery Rakes; Unit Drills; Pick-up Balers; Forage Harvesters; P.T.O. Drive Combines; Semi-Automatic Potato Planters and Transplanters; Down to the Row Thinners		.05	.04	.04	.04
GROUP V Engine driven and self-propelled Combines; Corn-drills; Milking Machines Hydraulic Loaders; Simple potato Planting Attachments		.04	.03	.03	.03
GROUP VI Grain Driers; Grain Cleaners; Rolls; Hammer Mills; Feed Mixers; Threshers; Tractors		.02	.02	.02	.01

TABLE 7: Estimated Hourly cost of Repairs and Spares as a Percentage of Purchase Price

FIGURE I

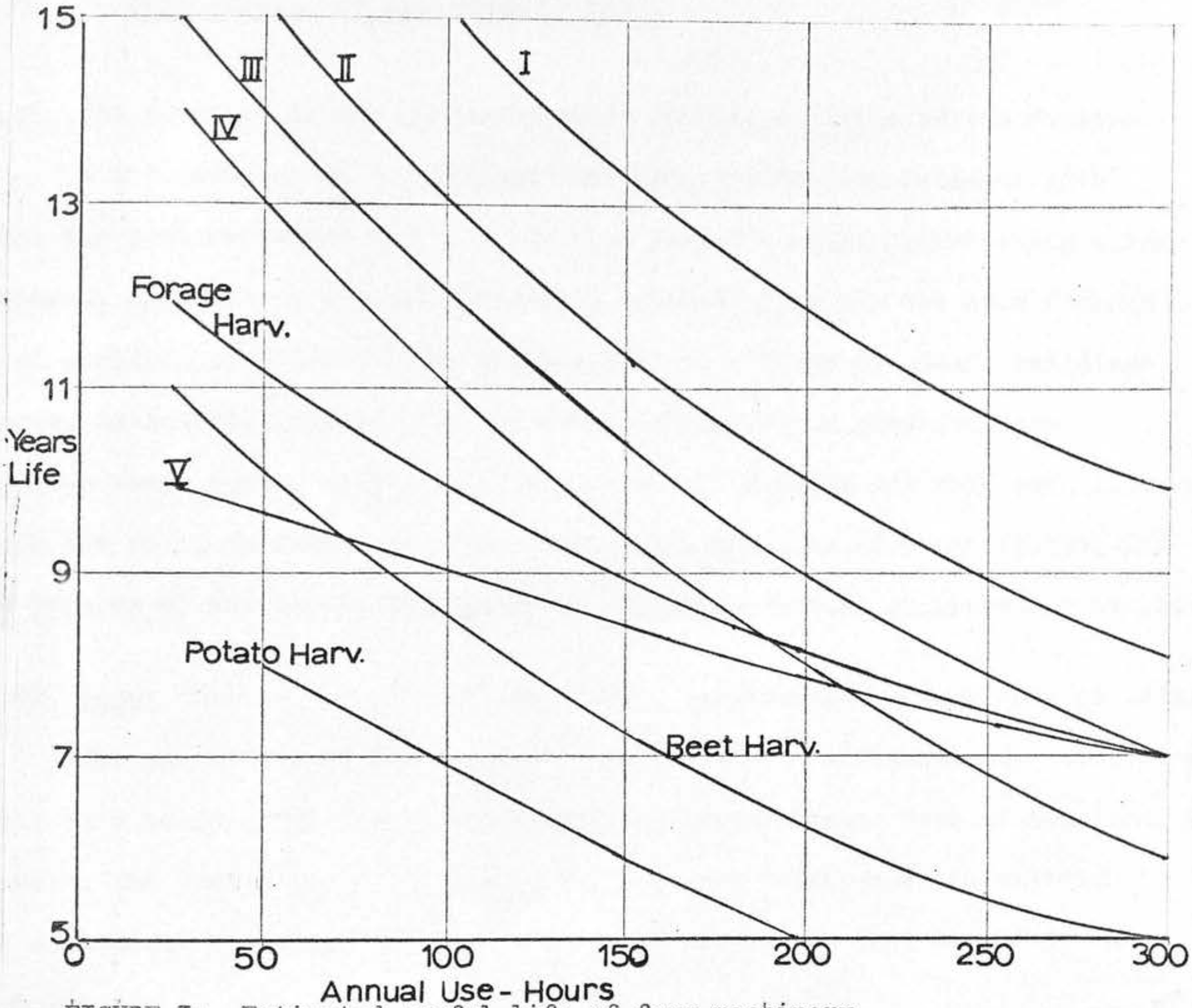


FIGURE I: Estimated useful life of farm machinery.

GROUP I Ploughs; Cultivators; Toothed Harrows; Hoes; Rolls; Ridges; Simple potato planting attachments; Grain Cleaners; Threshing machines.

GROUP II Disc Harrows; Corn Drills; Binders; Grain drying machines; Food grinders and mixers.

GROUP III Combine Harvesters; Pick-up Balers; Rotary Cultivators; Hydraulic loaders.

GROUP IV Mowers; Swath Turners; Side-rakes; Tedders; Hedge cutting machines; Semi-automatic potato planters and transplanters; Unit root drills; Mechan. root thinners.

GROUP V Fert. dist.; Comb. drills; F.Y.M. spreaders; Elevator potato diggers; Spraying machines; Pea cutter-windrowers.

10.0 Construction of the Planning Model

10.01 The solution to any problem depends for its validity on two factors – the accuracy of the information used, and the completeness with which the problem is described. For this reason a model representing a farm business, and used to plan that business, should allow for the main factors which would in practice affect decision making. These are land, buildings, labour, machinery, capital, the inter-relationships and substitutions possible among these, climate, and management. Climate has only been included in so far as it is likely to affect labour availability (Section 15.03), and the results of variations in managerial ability have been deliberately excluded.

10.02 Land: The number of acres available, sub-divided as necessary to allow for variations in fertility and workability. Allowance must also be made under this heading for restrictions applying to particular uses of the land, for example, the potato quota available, the farmers' preferences in relation to the rotational frequency of crops because of disease or soil fertility and workability.

10.03 Buildings etc: Used as a blanket term covering other permanent or semi-permanent assets on the farm. The available crop storage and handling capacity and livestock housing, the effects of limited availability of water for various purposes, the number of houses for farm staff etc. must be considered. It may be possible to increase the supply of some of these assets by expenditure of capital in which case the cost of so doing becomes part of the problem.

10.04 Labour: As with land, there are various categories of labour available. A man may be hired on a permanent basis, when a weekly wage must be paid, regardless of whether any work is done. In addition to this, he is generally available for overtime work, for which the hourly rate is higher than that of the basic weekly wage, but overtime work is only done, and paid for, if there is specific work to be done. As an alternative to, or more often, in addition to, the regular staff, casual labour may be employed, being paid on an hourly basis, at a rate normally somewhere between the two rates mentioned above. The availability of labour, especially of casual labour, may vary considerably with the district and the location of the farm in relation to centres of population, and this very often affects the working of a farm. Geo-climatic variations affect the organisation of a farm, partly by causing variations in the number of days on which cultivations are possible.

10.05 Machinery: This is virtually inseparable from labour since a degree of substitution is possible. The effect of the labour - machinery complex on the balance of cropping arises because some crops require relatively high inputs of labour and/or machinery, compared to others. The non-linearity of the relationship between machine cost per acre, and acres worked per machine, complicates the inclusion of machinery selection in a linear programming model. The selection of crops and crop acreages in arable farming is often affected by the number of men required as a team to handle a crop operation. For example, if potatoes are grown on a commercial scale, it may be necessary to employ 4 or 5 men, although these men may only be fully employed at potato lifting.

10.06 Capital: This is the common denominator of all factors affecting business decisions since it can be used to procure additional supplies of any limiting resource, provided that supplies are available. Also, being possibly restricted in quantity itself, the available supply must be utilised to the best advantage. Since the amount of capital used in a farm business varies throughout the year, the peak requirement will normally occur at only one period of the year, and when capital is restricted this period will be the area of activity limitation with regard to capital. Whether or not capital supply is limited, and from whatever source capital is obtained, a financially sound business must pay interest at a competitive rate on the capital employed.

11.0 The effect of incomplete problem representation (Constraint Test)

11.01 Linear programming can be used to demonstrate the effects of leaving out of the decision model, one or more of the factors outlined in Section 10.0. This was done using a hypothetical 1000 acre arable farm as a test-bench.

The matrix used for this test is shown in Figure J, the detail of representation being less than that used in later matrices, in order to reduce computer time. Labour selection, for example, is covered by one variable and four constraints, while in full scale matrices, 16 variables and 19 constraints are used. The purpose here, however, is to demonstrate the comparative effect on solutions to the same basic problem, of successively adding more of the factors affecting decisions, rather than to obtain actual working solutions. The problem is run in four stages, CT1 to CT4.

11.02 CT1 Contains 18 variables for crop production, crop disposal and livestock, with 15 constraints relating to the availability of land and buildings, rotation control, crop disposal, and livestock nutrition.

11.03 CT2 is extended from CT1 by adding one variable representing one full time man employed, supplying to each of four seasons of the year a fixed number of man hours, made up of the normal working hours suitable for outside work, plus an allowance for overtime hours. Four constraints are added to CT1, each one balancing supply and demand of labour in one season.

11.04 CT 3 is formed by adding 6 variables and 13 constraints allowing selection of machinery, to CT2. The variables represent tractors,

Figure J - Constraint Test Matrix

	Constraint No.		Requirement	Inequality sign	Potatoes 1ac	Wheat 1ac	Barley 1ac	Sugar Beet 1ac	Silage 1ac	Grazing 1ac	Cows 1	Cattle Wintered 1	Straw Fed 1T	CT 1 - LAND: Beet Tops Fed 1T	Soya Meal 1T	Barley Fed 1T	Barley Sold Autumn 1T	Barley Sold Spring 1T	Wheat Sold Autumn 1T	Wheat Sold Spring 1T	Potatoes Sold Autumn 1T	Potatoes Sold Spring 1T	CT 2 LAB.: 1 Man	CT 3 MACHINERY: 1 Tractor	1 Combine	1 Pot. Harv.	1 Plough	1 Beet Harv.	1 Forage Hv.	CT 4 - CAPITAL: Fixed Cap. £100	1st Qt. Cap. £100	2nd Qt. Cap. £100	3rd Qt. Cap. £100	4th Qt. Cap. £100	5th Qt. Cap. £100
					1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
		Functional			-45	-8.4	-.693	59	-11	-11	104	45	-.5	-.04	-44	-1	18	23.5	21	26.5	12	14.5	-800	-450	-450	-225	-285	-102	-90	0	-2.5	-2.5	-2.5	-2.5	-2.5
	1	Land Max.	1000		1	1	1	1	1	1																									
	2	Potato "	200		1																														
	3	Root "	360		1			1																											
CT 1 LAND	4	Wheat "	0		-1	1		-1																											
	5	Potato Balance	0		-10																1.176	1.307													
	6	Wheat "	0			-2.5													1	1															
	7	Barley "	0				-2									1	1	1																	
	8	Straw "	0				-1.5						1																						
	9	Beet Top "	0					-9.6						1																					
	10	Grazing Bal 30/6	0							-.5	.3165	.125																							
	11	" " 30/6	0						-.33	-.5	.4335																								
	12	S.E. Bal)	0						-26.9		28.3	24	-5.15	-1.9	-14.56	-15.75																			
	13	D.C.P. ") 100 lb	0						-3.8		4.23	2	-.157	-.31	-11.2	-1.7																			
	14	D.M. ")	0						51.5		-53.05	-48.6	19	3.58	20.16	19																			
	15	Court Space-10sq.F.	1000									5																							
CT 2 LABOUR	16	Labour - Season I	0		12.2	.9	1.9	6.8	.4	2.925		2.44											-387.3												
	17	" " II	0		3.8	.2	.2	31.2	6	.625		1.24											-912.8												
	18	" " III	0		18	4.7	2.4		1				.31										-558.8												
	19	" " IV	0		2	1.6	2	26.5				3.52		.78									-224.8												
	20	Tractors - Season I	0		5.5	.9	1.9	6.8	.4	1														-387.3											
	21	" " II	0		3.8	.2	.2	1.9	6	.4														-912.8											
	22	" " III	0		10.8	2.5	.7																	-558.8											
	23	" " IV	0		2	1.6	2	20.7						.39										-224.8											
	24	Combine Balance	0			1	1																		-200										
CT 3 MACH.	25	Pot. Harv. "	0		1																					-50									
	26	Plough "	0		1	1	1	1																			-125								
	27	Plough/Tractor "	0																					-1			1								
	28	Beet Harv. "	0					1																				-80							
	29	Forage Hv. "	0						1																				-125						
	30	Team Size-Combine	0																				-1		2										
	31	" " -Pot. Harv.	0																				-1			4									
	32	" " -Beet Hv.	0																				-1					4							
	33	Capital - Fixed	0								190													900	3000	800	120	450	400	-100					
CT 4 CAP.	34	" - 1st Qt.	0		31	6.6	1.78	13.38	6.7	8.7	-42.262				22	.5							200	12.5	-75	-25	5.25	-20	-17.5	100	-100				
	35	" - 2nd Qt.	0			1.2	.463	2	2.3	2.3	-42.262												200	12.5	-75	-25	-3	-20	2.5		100	-100			
	36	" - 3rd Qt.	0		7	.6	-1.55		2		-42.262	70	.05				-18		-21				200	12.5	75	-25	-3	-20	-17.5			100	-100		
	37	" - 4th Qt.	0		7			1.22			-42.262	-23		.04	22	.5		.25		.25	-12		200	12.5	-75	100	5.25	2	-17.5				100	-100	
	38	" - 5th Qt.	0									-92						-23.75		-26.75		-14.5												100	-100
	39																																		
	40																																		
	41																																		
	42																																		
	43																																		
	44																																		
	45																																		
	46																																		

ploughs and harvest machinery. Five constraints define tractor requirements, five constraints link arbitary capacity coefficients of machinery to crop acreages, and three constraints link machines to farm staff size, by the size of team required to operate each type of machine.

11.05 CT4 adds to CT3 six variables and six constraints allowing consideration of working capital requirements, described in five 3 month periods. The construction used is simpler and less accurate than that in the full working model. The more sophisticated representation of cash flows was not developed until after this test had been run, and is discussed in Section 14.05.

11.06 The comparative results of this test shown in Table 8, indicate that each expansion of the model has a significant effect on the solution, as the relative enterprise cost loads change.

11.07 Another factor affecting the validity of the decision reached is that of time. Management decisions in farming are not normally made solely on the consideration of one year's operation, since capital may have to be accumulated, or borrowings paid off over a specified period, or because of changes in technique or in the relative prices of products. This can be dealt with using dynamic programming, an extension of linear programming. A number of sub-problems, each of which represents the situation within one of a series of years, are linked together by those activities which are common to several years, and are continuous throughout them. This can be undertaken in either of two ways. The simple way is to solve the whole matrix representing several years operations, illustrated in Figure K, as one problem, the objective being

TABLE 8

Variable Name	CT_1	CT_2	CT_3	CT_4
	Enterprises only	Enterprises + Labour	Enterprises + Labour + Machinery	Enterprises + Labour + Machinery + Capital
Potatoes	200.0	200.0	200.0	193.1
Wheat				206.6
Barley		17.0	38.1	
Sugar Beet	160.0	61.5	26.3	13.5
Silage	207.7	259.0	264.1	205.5
Grazing	432.2	462.5	471.5	381.3
Cows	656.7	730.6	744.9	596.3
Cattle (W)	66.4			15.7
Straw Fed		25.6	57.1	
Beet Tops Fed	1536. 0	590.0	252.6	129.5
Soya Meal Fed	90.9	110.2	116.3	100.6
Barley Fed		34.1	76.2	
Bar. Sold-Aut.				
Bar. Sold-Spr.				
Wheat " -Aut.				
Wheat " - Spr.				516.4
Potat " - Aut.	1700.7	1700.7	1700.7	1641.8
Potat " - Spr.				
Men (Ex. Dairy)		11.2	16.0	15.4
Tractors			5.0	4.7
Combines			0.2	1.0
Potato Harvester			4.0	3.9
Ploughs			2.1	3.3
Beet Harvester			0.3	0.2
Forage "			2.1	1.6
Capital-Fixed				124,804
Capital-1st. Qt.				119,385
Capital-2nd. Qt.				106,158
Capital-3rd Qt.				89,411
Capital-4th Qt.				58,695
Capital-5th Qt.				43,440

TABLE 8: Effect of improving the decision environment description.

FIGURE K

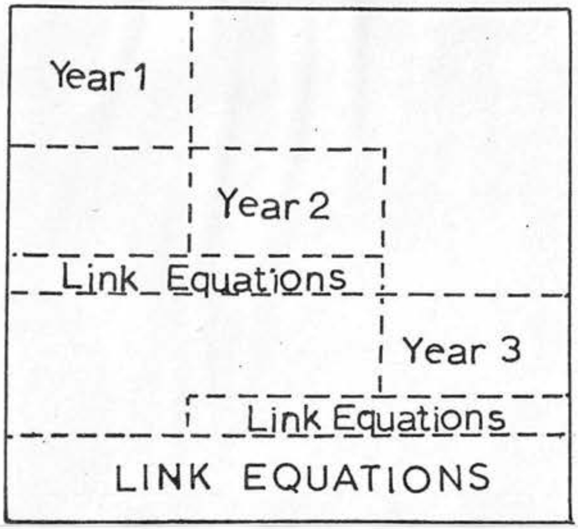


FIGURE K: Form of a Dynamic Programming Matrix.

maximisation of total margin over the whole period. This approach is only feasible for situations generating a small annual matrix and where only a few years are considered, since the size of the full matrix equals approximately (size of annual matrix x N^2), where N is the numbers of years projected. This puts most problems outwith the working space of available computers. The alternative to this is to apply the decomposition principle (see Dantzig (11) page 448) to dynamic programming, by which a solution is converged upon by alternately solving and updating the link matrix and the sub-matrices.

11.08 In this study, however, it was decided for three reasons to use static linear programming:

(a) It was intended, because of farmers' views, that capital would be regarded as non-limiting and non-repayable. This would eliminate progressive variation in farm organisation due to build-up of capital.

(b) It was regarded as unlikely that forecasts of medium term change trends in produce prices could be even moderately accurate, and therefore, although it was realised that returns would alter, it was thought that attempting to predict these changes could not bring any real improvement to the representation of the problem.

(c) Expanding the problem to cover a series of years, would greatly increase the computer time and cost required for solution.

12.0 Computer Program Development

12.01 At the time of commencing this study, computer facilities in Edinburgh had been little developed and no suitable linear programming program was available. Mr. A. Watson, of the Computer Unit, had just written, in Atlas Autocode, the computational core of an extended composite algorithm for linear programming, but emigrated before completing the data input and solution output sections beyond an embryonic stage. This programme was developed and extended to include a number of facilities. A copy of the programme is shown in Appendix F.

12.02 Input The main aims in the input section are ease of data preparation and checking. In the type of matrix used a large proportion (about 90%) of the coefficients are zero, and punching each of these onto tape is both time consuming and liable to error. The program is therefore so written that a series of, say, seventeen zeros can be represented in data by Z17, if desired. That is, the symbol 'Z', followed immediately by a figure indicating the number of separate zero coefficients to follow. Also, the symbol 'N' is placed at the end of each matrix row, so that the number of coefficients in every row can be automatically checked by the computer.

12.03 Output One of the main attributes of linear programming is the peripheral information which can be made available by examination and analysis of the solution matrix. The output section of the programme was developed so that some of these calculations might be carried out by the computer, and the results printed out.

If the solution matrix is of M+1 rows and N+1 columns and the coefficients in the matrix are represented by $A(i,j)(i=1,2...,M;\ j=1,2...,N)$, then in the solution there are M basic variables, i.e. physical quantities, and N non-basic variables i.e. identities which are not included in the physical solution. The values of the basic variables are given by $A(i,N+1)$, and are identified by labels set when the original problem matrix was formulated. If $A(i,N+1)$ represents an identity which appeared as a variable in the original problem matrix, then the value indicates the number of units of that activity which should be undertaken. If it represents an original maximum constraint then its value indicates the unused surplus of that resource, and if it represents an original minimum constraint the value shows by how much that minimum has been oversupplied.

The marginal values of non-basic variables are $A(M+1,j)$. In the case of an original variable this indicates the amount of margin increase or cost decrease per unit, required in order that the variable be feasible to enter the solution, and in the case of an original constraint, the marginal value indicates the worth of relaxing that constraint by one unit.

12.04 The above information i.e. the physical quantities of basic variables and the marginal values of non-basic variables, is available from the solution matrix directly. By further analysis of the solution matrix coefficients more information can be obtained.

12.05 The number of units of a non-basic variable to which the marginal value given applies: If, in the 'i'th equation of the matrix, the non-negative coefficient $A(i,j)$ appears in the column 'j' which represents a non-basic variable NBV, then if one unit of NBV were introduced, the value $A(i,N+1)$

of the 'i'th basic variable would be reduced by the amount of $A(i,j)$. Thus the number of units of NBV which can be introduced up to the point where the basic variable value $A(i,N+1)$ becomes zero, is $\frac{A(i,N+1)}{A(i,j)}$. Beyond this point, the whole solution would change, and therefore the greatest number of units of NBV which could be brought into the solution with the marginal value adjustment indicated by $A(M+1,j)$, is that which would cause only one basic variable value to become zero i.e. Max $NBV(j) = \text{Min} \frac{A(i,N+1)}{A(i,j)\geq 0}$

In the case of non-basic variables representing original constraints, the amount of resource <u>decrease</u> to which the marginal value applies can be calculated from Min $\frac{A(i,N+1)}{-A(i,j)\geq 0}$

The importance of this is that if, from the marginal prices, it is found that a change of say 2% in the gross margin of an enterprise, which might arise from a $1\frac{1}{2}$% change in product price, would make that enterprise a feasible entrant to the solution, then this would indicate potential instability of the plan, since a $1\frac{1}{2}$% change in product price is very possible. If, however, the 2% margin change applies to the introduction of only a very small number of units relative to the general scale of the solution, then the effect of the instability is reduced. Also, the unit marginal value of scarce resources is of considerable value for comparison with the market value of those resources.

It is possible also to calculate a new solution, assuming that any one of the marginal value changes should occur, by deducting from the Basic Variable values $A(i,N+1)$, the results of multiplying the coefficients $A(i,j)$ in the column 'j' representing the non-basic variable NBV, by the maximum value calculated above per NBV i.e. $A(i,N+1) - \left(A(i,j) \cdot \text{Min} \frac{A(i,N+1)}{A(i,j)\geq 0} \right)$ where $j = NBV$, $i = 1, 2 \ldots\ldots M$ This calculation was not included in the computer program because of the very large volume of output which would result.

12.06 The range of margins/costs for original variables, within which the solution calculated will remain optimum: The necessary condition for a basic variable is that its relative cost factor (or marginal value) be zero. Therefore if a change is made to the original price of a variable such that the relative cost factor of a non-basic variable becomes zero, then that non-basic variable becomes a candidate to enter the solution. The marginal value of a non-basic activity 'j' is given by: Original price of non-basic activity (which would be zero if it were originally a constraint)- $\sum$ (solution matrix coefficients in the column representing the non-basic activity) · (original prices, where such exist, of the basic activities to which each coefficient relates) i.e. $cj = c^oj - \Sigma Aij \cdot c^oi$ Thus prices '$\bar{c}^oi$' which will allow the marginal value 'cj' of each non-basic variable to equal zero, can be calculated for each basic variable. If $S = \Sigma Aij \cdot c^oi$ for all i other than one called 'x', then $cj = c^oj - S - (Axj \cdot c^ox)$ and $c^ox = \frac{c^oj-cj-S}{Axj}$ Where $cj = o$, $\bar{c}^ox = \frac{c^oj - S}{Axj}$ and thus the change in the original price of 'x' which will allow cj to become zero, is $cx - c^ox = \frac{cj}{Axj}$ From this a series of 'new' original prices for a basic variable can be calculated, each of which will allow the marginal price of one basic variable to become zero, and the range of price which can be allowed each basic variable 'i' without altering the solution will be from $(c^oi + \text{Max } \frac{cj}{Aij} < 0)$ to $(c^oi + \text{Min } \frac{cj}{Aij} > 0)$

Descriptions of the various aspects of the analysis of the solution matrix of a linear programming problem are given by, for example, Puterbaugh et al.(6), Tyler (7), Smith and Barnard (8), Blattner (9) and Tyler (10). An example of the solution output from the program is shown in Figure L.

12.07 In addition to input and output, some improvements were made to the computational part of the program. The main change was aimed at improving the efficiency of selection of the outgoing variable (pivotal row) at each

DATA NO.= 30.720
LINES= 150ATA O.K.

IT.NO.	PV.C	PV.R	LV.B	FN.B	OBJ.FN.	UNITS 1

BASIC FEASIBLE SOLUTION OBTAINED

IT.NO.	PV.C	PV.R	LV.B	FN.B	OBJ.FN.	UNITS 1
1	9	7	1007	9	0.00	
2	11	8	1008	11	0.00	
3	7	6	1006	7	0.00	
4	1	13	1013	1	0.00	0.00
5	17	2	1002	17	-6511.77	96.00
6	2	14	1014	2	-9699.28	96.00
7	3	5	1005	3	-14461.81	96.00
8	5	1	1001	5	-20453.82	96.00
9	4	9	1009	4	-21409.97	96.00
10	10	1	5	10	-21513.64	96.00
11	6	6	7	6	-21660.47	96.00

OPTIMAL SOLUTION OBTAINED.
OBJ.FUNCT.= -21660.4683

BASIC VARIABLES

BV.	VALUE	CHANGE	P.CENT	NBV.IN	PERMISS. RANGE		CHANGE	P.CENT	NBV.IN
10	5.01	-20.00	10.6	8	170.00	220.00	30.00	15.8	1009
17	6.76	-1524.23	190.5	1002	-2324.23	-444.09	355.91	44.5	1013
3	96.00	-11.74	147.3	1005	-19.71	-3.02	4.95	62.1	5
6	100.31	-1.46	1.0	7	148.54	INF.	INF.		
9	20.16	-20.00	7.4	8	250.00	293.56	23.56	8.7	5
11	39.84	-23.56	10.7	5	196.44	240.00	20.00	9.1	8
4	241.78	-2.05	120.7	5	-3.74	7.31	9.01	531.3	1005
1	96.00	-71.80	148.4	1002	-120.18	INF.	INF.		
2	46.22	-27.73	47.9	1014	30.21	69.76	11.82	20.4	5

BV.	VALUE
1003	113.78
1004	46.22
1010	687.33
1011	2451.18
1012	2212.62

NON-BASIC VARIABLES

NBV	M.V.P	P.CENT	REQ.PR	UNITS IN	BV.OUT
7	1.67	1.0	171.67	87.65	6
8	20.00	9.1	240.00	5.01	10
5	4.95	47.9	15.28	21.00	10
12	1027.02	102.7	27.02	24.22	10
13	1027.02	102.7	27.02	24.22	10
14	1027.02	102.7	27.02	24.22	10
15	1027.02	102.7	27.02	24.22	10
16	1027.02	102.7	27.02	24.22	10

NBV.	M.V.P	UN.INCR	BV.OUT	UN.DECR	BV.OUT
1013	0.65	1400.57	1004	-818.53	10
1014	2.06	363.29	10	-621.62	2
1005	11.74	157.70	10	-96.00	9
1009	3.00	50.11	10	-398.40	11
1001	27.02	41.44	1004	-24.22	10
1006	14.25	INF.		-1056.00	6
1007	24.00	398.40	11	-50.11	10
1008	19.00	INF.		-50.11	10
1002	71.80	14.03	10	-22.46	1004

iteration. Originally, selection was based on discovering Min $\frac{A(i,N+1)}{A(i,p)}$ where 'p' is the already selected pivotal column. In the type of matrix used the majority of the constants A(i,N+1) are zero, the equations being formulated to balance supply-demand relationships between variables. Thus the row giving Min $\frac{A(i,N+1)}{A(i,p)}$, where 'p' is the pivotal column, is the first row encountered out of the many where A(i,N+1) = 0. This is not only inefficient, but may lead to degeneracy through circling (see Dantzig (11) pp 100, 210, 228). Dantzig (11) (p 222) suggests the use of the lexicographic rule for resolving degeneracy, wherein among the rows which tie for Min $\frac{A(i,N+1)}{A(i,p)}$, that one is selected which has Min $\frac{A(i,p)}{A(i,1)}$ i.e. the pivotal column coefficients of the tied rows are divided by the tied-row coefficients in the first matrix column, and the row giving the smallest result is selected. If there are still ties, the process is repeated on the remaining tied rows with the second column to find Min $\frac{A(i,p)}{A(i,2)}$, and continues through the columns until there is a unique choice for the pivotal row. Orchard-Hays (12) has suggested that in practice, more efficient selection is made if, from among the tied rows, that one is selected as the pivotal row which has the largest value for A(i,p). Figure M shows the relationship between values of the objective function and the number of iterations, when the same problem was solved by programs using random choice, the lexicographic rule, and the Orchard-Hays method of selecting the pivotal row when a tie exists.

12.08 Normal linear programming problems should reach a solution in not more than 3M iterations, where there are M constraints (Dantzig (11) p 160), but to avoid waste of computer time the program was developed to store the problem on magnetic tape after any given number of iterations. The time taken per iteration with the compiler in use was calculated as 0.000728(M+1) + 0.34

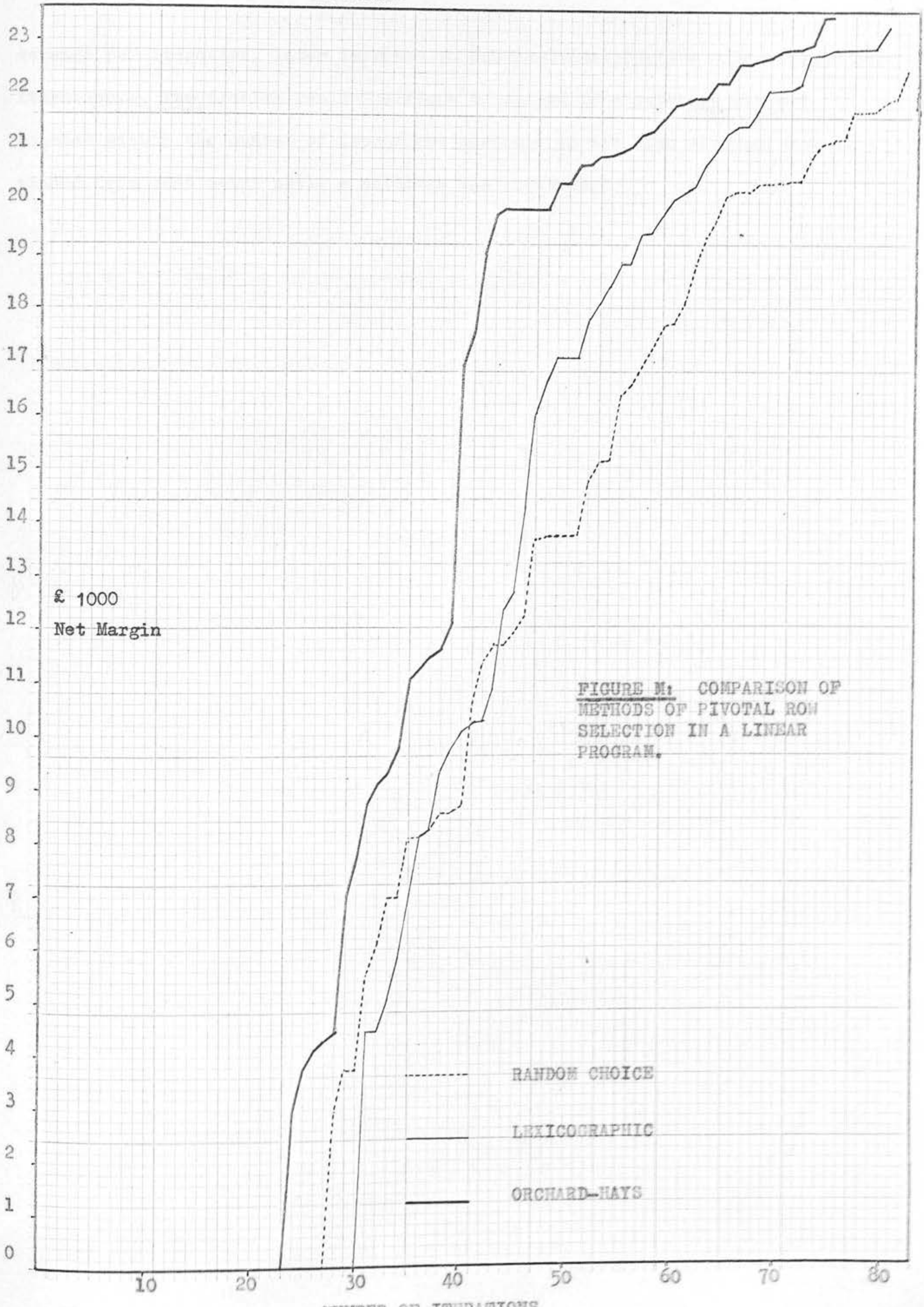


FIGURE M: COMPARISON OF METHODS OF PIVOTAL ROW SELECTION IN A LINEAR PROGRAM.

seconds per iteration, later improved to $0.0006585(M+1)(N+1) + 0.14$ seconds per iteration. The problem could therefore be stored if a solution was not reached within the number of iterations possible in the time allowed, and continued from that point until a solution was obtained.

13.0 Construction of the planning matrix

13.01 The following sections discuss some of the relationships in the matrix used to produce optimum plans for the farms studied, and the derivation of some of the coefficients. The complete matrix is given in Appendix G. The blanks in the constraint column would, in describing a particular problem, be filled by limits relating to the farm being programmed, and the annual cost of and capacity of machines would be set according to circumstances.

13.02 The inequations relating land use to acceptable husbandry practice are mainly straightforward.

Rows (62,67,72,77,82) limit the total crop acreage on each soil type, to the available acreage.

Rows (69,74,79) limit sugar beet to one third of the acreage, on three soil types.

Rows (65,70,75,80) allow cereals to be grown only on 80% of the acreage, on four soils, while on Thin soil Row 84 limits the total cropping acreage to 75%. The actual requirement here, is that at least 25% of Thin Land shall be in grass. The programme assumes all inequalities to be of the form $\geqq$, but does allow the use of negative values in the constraint column of the initial matrix, a basic feasible solution being arrived at before optimisation is proceeded with. Thus, for 100 acres of land, a 25% minimum of grass could be written as $-25 \geqq -1 \cdot$ (acres of grass). Because of the consumption of computer time in reaching a basic feasible solution when negative constraints are used, it is preferable where possible to reverse this type of constraint by writing, for the above example, $75 \geqq 1 \cdot$ (acres of crops other than grass).

Rows (71,85,81,76). Wheat can only be grown following potatoes or grass on Heavy and Medium-heavy land. On Medium land wheat can follow 50% of the sugar beet crop, and on Light land all of the beet acreage, in addition to potatoes and grass. Row 66, relating to wheat and potatoes on Heavy land, is a special case, and is discussed later in this section.

Rows (63,68,73,78,83). The permitted frequency of potato cropping varies with the variety and the significance of eelworm. The limitations decided upon were: For maincrop potatoes $\leq$ 1 year in 5; for early maincrop potatoes, $\leq$ 1 year in 4; for early potatoes on Medium land $\leq$ 1 year in 3; for early potatoes on light land $\leq$ 1 year in $2\frac{1}{2}$. The different varieties are mutually exclusive - if 20 acres of maincrop potatoes are grown annually on a 100 acre block of land, then no other potato variety can be grown. A constraint allowing the selection of more than one variety of potato on the same block of land but in such proportions that no cropping frequencies are ignored, is written as: TOT. ACRES OF LAND AVAILABLE $\geq$ (5 · MC) + (4 · EMC) + (3 · 2E) + (3 · 1E) From this, if maincrop (MC) potatoes are selected, five times their acreage is deducted from the total land available for other varieties. If early maincrop potatoes (EMC) are also selected, the land available for early (2E,1E) potatoes becomes: (Total Acreage) - (5 · MC acreage) - (4 · EMC Acreage).

Rows (64,66). On heavy land, potatoes must be preceeded by grass. Wheat, as stated earlier, can be grown only after grass or potatoes. Writing these two requirements as separate constraints is fallacious, since the same acreage of grass can be followed by both wheat and potatoes:

		Potatoes	Wheat	Grass
MAX. POTATOES 0	$\geq$	1		-1
MAX. WHEAT 0	$\geq$	1	1	-1

In fact, both potatoes and wheat are limited to the acreage of grass grown (as one year ley) since WHEAT $\leq$ POTATOES + (GRASS - POTATOES) i.e. WHEAT $\leq$ GRASS. Thus the constraints become:

		Potatoes	Wheat	Grass	
MAX. POTATOES	0 $\geq$	1		-1	(Row 64)
MAX. WHEAT	0 $\geq$		1	-1	(Row 66)

Although early potatoes can be grown without irrigation, in East Lothian the yield is in most years considerably increased by irrigation. Only two of the farms had access to sufficient water, and only these therefore were considered as suitable for early potatoes, a constraint (Row 61) being included to relate the water requirements of potatoes, at $1\frac{1}{2}$ acre inches per acre, to the water available during mid May to mid July. In earlier models, irrigated grazing was included in this balance, at 2 acre inches per acre.

13.03 Grass was considered to be utilisable as grazing, hay, silage cut once, or silage cut twice, but while the grass growing ability of the types of land was known to vary, to include each of the four methods of grass utilisation as a cropping variable on each land type would be wasteful of matrix space. Therefore, one cropping variable "Grass" was entered for each land type and four utilisation variables were included in the matrix. Production and utilisation are connected by a balancing constraint (Row 44) which gives appropriate weight to the production potential of different soils, based on hay yield, the utilisation variables assuming the yield level obtained from heavy or medium heavy land.

13.04 Silage requires some form of storage, and two alternatives were included - horizontal pit and sealed tower. The wastage rate between ensilage and utilisation varies depending on the method of storage and the coefficients relating to silage storage/utilisation must be adjusted accordingly. MacHardy (13) also encountered this problem, and adjusted the yield of silage per acre. However, he also based storage requirements and cost on these adjusted yields, although the yield variation arises during storage, not previous to it. Assuming a yield of 13 tons per acre of pit silage, with 30% wastage, MacHardy calculated the equivalent yield from a sealed silo, with only 10% waste, as $\frac{90}{70} \times 13 = 16.7$ Tons/acre. This appeared in matrix L4 as:

	Iac. Silage	1T Hor.Silo	1T Tower Silo	10T Sil.Fed
Silage Storage 0 $\geq$	-1	.078	.068	
Silage (balance 0 $\geq$		-1	-1	10
Cost Row Z =	1.04	.02	.064	0

In the present case, calculation was based on the assumption of yields of mature silage of 9T/acre for one cut, and 15T/acre for two cuts when stored in a horizontal pit, with a wastage rate of 30%. It was assumed that wastage would be cut to 10% if tower storage was used (Nash (14)). The fresh grass tonnage, to yield 9T of silage with 30% wastage, must be $9 \times \frac{100}{70} = 12.8$ Tons, and for 15T of silage, 21.4T of grass must be produced. Thus, if 1 acre of grass is cut once for silage, storage for 12.8 Tons of fresh grass is required, regardless of the type of store. The storage variables were entered in units of 1000 cubic feet. Assuming the density of finished silage to be 50 cu.ft./ Ton, and adjusting by a factor of 1.25 to allow for settling, gives a space requirement of 62.5 cu.ft. per ton of grass cut for ensilage. Thus 1000 cu.ft. will contain $\frac{1000}{62.5} = 16$ tons of grass. At this point in the process the variation in wastage takes effect. Sixteen tons of grass ensiled in a pit, with 30% wasted, would give 11.2 tons of silage. Using a tower silo with 10% wastage, 14.4 tons of silage would be obtained from 16 tons of grass. Thus a silage storage balance and a consumption balance are required:

	1 ac. 1 cut	1 ac. 2 cuts	Thous. c.f. Pit	Thous. c.f. Tower	10T Sil. Fed	
Sil. (Use) 0 ≥			-11.2	-14.4	10	(Row 47)
Sil. (Store) .0 ≥	-12.8	-21.4	16	16		(Row 48)

13.05 The relationship between the growth of grass and the consumption of it by grazing livestock is complicated and to define it accurately would require more knowledge than is presently available, and also a considerable amount of matrix space. The factor of matrix size is important since the KDF9 computer used can only handle problems up to a matrix of approximately 11,000 coefficients, but results could be obtained in 24 hours. Problems larger than this had to be processed on an Atlas computer, with a 6-7 day turnround period.

Therefore the method used to describe the grass-livestock relationship is an approximation, based upon dividing the grazing season at 30th June into two parts, controlled by two constraints (Rows 45,46). It is estimated* that 55% of the annual production from grass is achieved by the end of June. Also, hay and silage provide aftermath grazing in the latter part of the season. The proportions of annual production available as grazing were estimated as

* Dr. J.C. Holmes - personal communication.

as: Hay - 25%; Silage (1 cut) - 40%; Silage (2 cuts) - 15%. The estimation of approximate consumption is based on the observation that in practice, two 10 cwt. cattle will keep pace with the early summer growth from one acre of well managed grazing, and the calculations are summarised in Table 9.

TABLE 9

Stock (Type) (No. per unit)	LWt @ 1 May (cwt)	LWt @ 1 Jly (cwt)	LWt @ 1 Nov. (cwt)	1 May - 30 June		1 July - 31 Oct.	
				Grass 'used' X Tons	Anim/ac.	Grass 'used' X Tons	Anim/Ac.
S. Cattle (1)	7.3	8.4	10.0	0.216	2.55	0.506	0.89
W. Cattle (4)	9.214	10.0	-	0.1058	2.08	-	-
18m Beef (1)	4.29*	4.46	5.85⁑	0.06	4.58	0.2129	1.59
Ewes (10)				0.7857	7.0	0.9	5.0
D. Cows (1)	11.0	11.0	11.0	0.3784	1.45	0.7568	0.59

TABLE 9: Summary of grass consumption coefficients for grazing livestock

* From 1st June

⁑ To 1st October.

If X tons of grass are grown on one acre in one year, then in the two months from 1st May to 30th June, the average rate of growth is $\frac{0.55X}{2}$ = 0.275X tons/month. Thus, 20 cwt. of cattle consume 0.275X tons of grass per month = 0.01375X Tons/cwt/month. From this, grass fattened cattle with an average weight of 7.85 cwt. (7.3 cwt. to 8.4 cwt.) during the period 1st May to 30th June will require 7.85 x 0.01375X x 2 = 0.216X tons of grass per head in the time that 1 acre produces 0.55X tons of grass. That is, they will require $\frac{0.216X}{0.55X}$ = 0.393 acres/head (= 2.5 animals/acre). In the period from 1st July to 31st October, given a liveweight gain of 2 lb/day in early summer, and $1\frac{1}{2}$ lb/day thereafter, these cattle would have an average weight of 9.2 cwt., and would require 9.2 x 0.01375X x 4 = 0.506X tons of grass, during the period when an acre produces 0.45X tons. This is equivalent to a stock density of $\frac{0.45X}{0.506X}$ = 0.89 cattle per acre. For winter fattened cattle allowance is made for a proportion of the cattle being finished on grass. The assumption made, is that for each unit of two cattle fattened $^2/_5$ of an animal goes out to grass, and the average weight of an animal during the period from 1st May to 30th June, is 9.607 cwt. (9.214 - 10 cwt). Therefore, for each unit of this type of livestock the tonnage of grass required = 9.607 x 0.4 x .01375X x 2 = 0.1058X tons. There is no grass requirement for these cattle from 30th June onward.

Calves for fattening at 18 months are bought in October, put onto grass at the end of May, and housed again at the end of September. Their average weight is taken as 490 lb. in June and 578 lb. in the period 1st July to 30th September, giving grass requirements of 0.0601X tons and 0.2129X tons respectively, per animal.

With sheep, it was assumed that the grass would carry the equivalent of 7 ewes + lambs per acre up to 30th June, and 5 per acre thereafter. The seasonal grass consumptions of 10 ewes are therefore $\frac{0.55X}{0.7}$ = 0.7857X tons and $\frac{0.45X}{0.5}$ = 0.9X tons.

Although not shown in the matrix (Appendix G), irrigated grazing for dairy cows was included in one model. Two cow variables were used, one for a system using self feed silage in winter and the other representing byre housing and mixed feeding.

It was assumed that careful irrigation and fertiliser applications could reduce seasonal growth variations and stocking rate was set at two cows per acre over the whole season. Although no allowance was made for stock other than cows to use irrigated grass, cows were permitted to use ordinary grazing, by including one exchange variable "Cows on non-irrigated grazing", to avoid using two matrix columns in duplicating the cow enterprises. The exchange variable was given a cost factor of - £5 to allow for possible yield reduction. The grass consumption coefficients for cows on ordinary grazing were calculated on the same basis as for other cattle, with allowance made for a higher production level from the stock by adding 25% to the consumption/cwt/month. The construction used is shown below, including in the constraint column the acreage of permanent grass in each case.

	Irr. Gr.	Graz.	Cows S.F.	Cows Byre	Cows on non-irr.Gr.	
Graze 30 June:Pm.Grass ≥		-.55			.3784	(Row 45)
Graze 30 June :PM.Grass ≥		-.45			.7568	(Row 46)
Cow Grazing : 0 ≥	-1		.5	.5	-.5	

13.06 Where there is more than one way of disposing of a crop, the crop growing activity is given a negative cost factor which is normally equivalent to the variable costs of growing one acre of the crop. The growing activity is tied by a balancing constraint to disposal variables which have cost factors equal to the revenue from or cost of, disposal. In the case of wheat (Row 50) this is straightforward, two sale times, spring and autumn, being considered. With barley (Row 51) in addition to these two sale times, the grain can be included in livestock rations, and some classes of stock (barley beef, pigs, sheep, and 18 month beef) have specific barley requirements. Because of possible feed barley shortage the opportunity of buying barley is included, again in autumn and spring.

The existing grain storage capacity on each farm, required for grain sold in spring or bought in autumn, constitutes a constraint value. Two variables "Grain in Courts" and "Grain in potato store" are included to allow the use of these locations if necessary, 7 sq.ft. of court space per ton of grain being needed at 7 ft. deep, and potatoes being substituted ton for ton. (Row 60) As it is not possible to use barley bought in spring to feed stock during the preceeding winter, the tonnage of barley bought in spring is limited to the calculated summer feed requirements of barley beef and pigs (Row 52).

	1 ac. Barley	10T Bar. Sold		10T Bar. Bt.		10T Bar Fed	10T Grain Courts	Bar. Beef	Sheep
		Aut.	Spr.	Aut.	Spr.				
Row 51: 0 ≥	-1.85	10	10	-10	-10	10		1.95	0.344
Row 52: 0 ≥					10			-.8125	
Row 60: 0 ≥	1.85	-10		10			-10		

Storage and disposal of maincrop potatoes is controlled by two constraints - earlier varieties being sold at lifting. The storage control (Row 59) states simply that the total tonnage grown must not exceed the available storage, supplemented by the use of court space at 7 sq.ft/ton if required. Disposal (Row 49) is complicated by shrinkage and the removal of brock reducing the quantity of saleable potatoes. From data produced by Nash (15) it was decided that potatoes stored for a short time only (autumn sale) would not be affected by shrinkage, but that there would be 5% brock. Thus to sell ten tons (Activity 55), 10.527 tons must be grown. The remaining 0.527 tons of brock are available as feed. Where potatoes are stored under good conditions until early spring, about 7% shrinkage loss is to be expected, with disease damage increasing the brock to 10% of the original crop. Therefore, in order to sell 10 tons of potatoes after overwinter storage, $\frac{10}{0.83}$ = 12.048 tons must be grown, and 1.2048 tons are available for feed.

	1 ac. M.C.Pot.	10T Pot. Sold		10T Pot. in Court	
		Aut.	Spr.		
Pot. Balance: 0 ≥	-10	10.527	12.048		(Row 49)
Pot. Storage: x ≥				-10	(Row 59)

Brock potatoes are assumed to be suitable for stockfeed, and appropriate entries are made in the nutrient balances (<u>See Appendix H.</u>)

13.07 The constraint controlling the use of court space (Row 58) is fairly simple. The cattle space requirements assumed are:

Barley Beef on straw - 25 sq.ft/head; Barley Beef on slats - 13 sq.ft/head; Winter fattened cattle - 52 sq.ft/head; 18 month beef - first winter, 20 sq.ft/head, second winter 45 sq.ft/head, total 65 sq.ft/head. In the case of Barley Beef on slats, an adjustment is made to the capital requirements and to the enterprise margin to allow for the cost of installation of slats in existing buildings. In addition to livestock, courts space may be used for potato or grain storage on the basis of 1 ton of either crop requiring 49 cu.ft.

stored at 7 ft. deep. No variable is included in the model to allow the construction of extra covered accommodation because of the open endedness of capital supply, which could lead to an infinite solution, unless some limitation of managerial capacity were included. The quantitative definition of managerial capacity is beyond the scope of this thesis.

The size of the pig enterprise, which is intended only as a means of utilising slack court space and labour during the summer, is limited by the suitable space available. Pigs can only occupy space used by cattle bedded on straw and at grass during the summer. The space requirement per baconer is reckoned to be 13 sq. ft. and therefore the constraint limiting the size of the pig enterprise allows 4 pigs to be kept for each unit of winter fattened cattle, and 5 for each unit of 18 month beef. (Row 57).

To control the use of wheat straw for litter and barley straw for feeding and/or litter, three constraints and two variables, "Straw Fed" and "Litter", are used.

	1 ac. Wheat	1 ac. Barley	10T Str.Fed	10T Litter	Cows Byre	
Straw Bal. (Tot) :0 ≥	-2.5	-1.85	10	10		(Row 54)
Straw Bal.(Feed) :0 ≥		-1.85	10			(Row 55)
Straw Bal.(Litter) :0 ≥				-10	1.0	(Row 56)

One constraint (Row 54) relates total straw yield to total straw utilisation. A second constraint (Row 55) limits the amount of straw fed, to the total yield of barley straw, and a third (Row 56) relates the value of the variable "Litter" to the requirements of the stock. The amounts of straw required to bed the various classes of livestock were based on suggestions in various publications adjusted in accordance with the known straw consumption on the farms in the study. They are listed in Table 10, including dairy cow requirements.

TABLE 10

		Tons Straw/unit
Barley Beef:	25 Sq.ft. occupied for 12 months -	1.1715
Pigs (10):	130 sq. ft. occupied for 145 days -	0.57
Winter Cattle:	52 sq.ft. occupied for 180 days -	0.7076
18 Month Beef:	(20+45) sq.ft. occupied for 7 mths. -	0.8808
Dairy Cows (byre):	One stall occupied for 210 days -	1.0

TABLE 10: ANNUAL STRAW LITTER REQUIREMENTS OF LIVESTOCK

The disposal of organic manure is controlled by Row 40. Four variables are used to allow F.Y.M. to be spread on the land, as labour is available, at any time of year except from 16 April to 20 June. The weight of dung produced by livestock during the time spent inside was estimated from various sources, and added to the amount of straw required in each case (Table 10) to get the weight of F.Y.M. to be disposed of, as shown in Table 11. In the case of Barley beef on slats, and dairy cows on self feed silage, no straw is used.

TABLE 11

		Tons FYM/Unit
Barley Beef (straw)	-	6.335
Barley Beef (Slats)	-	4.4*
Pigs	-	3.91
Winter Cattle	-	5.625
18 Month Beef	-	5.1658
Dairy Cows (S.F. Silage)	-	5.156
Dairy Cows (Byre)	-	6.156

TABLE 11: WEIGHT OF F.Y.M. PER LIVESTOCK ACTIVITY PER YEAR

* This has been reduced by 15% to compensate for the convenience of handling as sludge from a large storage space.

13.08 The provision of feed supplies for livestock is controlled by three constraints. Row 41 provides that the total requirement of Starch Equivalent shall not exceed the total supply; Row 42 gives similar control over the consumption of Digestible Crude Protein; Row 43 ensures that the amount of Dry Matter in the feed does not exceed the capacity of the stock to consume dry matter. The assumed nutrient values of the feeds available within the model (taken from Watson and More (16)), and the calculation of livestock nutrient requirements, are given in Appendix H.

14.0 Control of Capital in a Linear Programming model

14.01 The supply and consumption of capital in the model shown in Appendix G, are subject to constraint rows 1-7. There are two ways of including the effects of money requirements in a linear programming model of a farm business and either can be used with varying precision. The precision depends on the number of sub-divisions of a year that are used to describe the needs of the enterprises for money. Stewart (17) points out that it is unrealistic to balance the annual sums of enterprise cash requirements against a single capital constraint, as is often done (for example, by Candler (18)) since the peak levels of enterprise cash requirements may arise at different times of the year and will not be competitive. For example, store pigs fattened from May to October may require an outlay of £14 per head before any revenue is obtained from them, and store lambs fattened from November to February might require £6 per head. These two enterprises are in no way competing for money, and with a supply of £420, 30 pigs <u>and</u> 70 lambs could be fattened. Therefore, it is essential that cash requirements be described in periods short enough to reflect probable inter-enterprise competition for money. In this model the periods are of two months each, commencing on 1st March, giving the cash flow to and from each enterprise over 6 periods. The sum of the cash flow of each activity is equal to the cost row entry of the activity.

14.02 One method (A), used by Stewart (17), of setting up the capital control section of a linear program matrix, is to constrain the capital availability in each period of the year. The matrix coefficients linking the activities to these constraints are the cumulative net cash flows from each activity. Gross margins from pig and lamb fattening might be made up as follows:-

Pigs			Lambs		
Store Pig	= 8.0	(May-June)	Store Lamb	= 4.0	(Nov-Dec)
Feed	= 2.0	(May-June	Forage	= 1.0	(Nov-Dec)
Feed	= 4.0	(July-Aug)	Concentrates	= 1.0	(Jan-Feb)
	14.0			6.0	
Fat Pig	= 16.0	(Sept-Oct)	Fat Lamb	= 7.0	(Mar-Apr)
Costs	= 14.0		Costs	= 6.0	
Margin	2.0		Margin	= 1.0	

The bracketed dates indicate the periods during which the inputs would be used, or the produce disposed of and the money involved would be paid or received, so that the cumulative balances entered in the matrix would be as in Table 12.

TABLE 12

Cost Row	2.0 1 Pig	1.0 1 Lamb
May - June 420 ≥	10.0	
July - Aug 420 ≥	14.0	
Sept - Oct 420 ≥	-2.0	
Nov - Dec 420 ≥	-2.0	5.0
Jan - Feb 420 ≥	-2.0	6.0
Mar - Apr 420 ≥	-2.0	-1.0

TABLE 12: METHOD 'A' OF CAPITAL CONSTRUCTION FOR L.P. MATRIX (AFTER STEWART)

14.03 In a second method (B), used by McFarquhar (20), the coefficients represent the net cash flows of the enterprises for each period separately, the capital limit is entered in the first constraint only and cumulation is done by adding a variable to represent the net cash position of the whole business in each period. The value of this variable is the sum of the cash inflows/outflows for one period, and is added to the balance for the next period. i.e. The surplus or deficit is carried forward, as illustrated in Table 13.*

TABLE 13

Cost Row		2.0 1 Pig	1.0 1 Lamb	Bal MJ	Bal JA	Bal SO	Bal ND	Bal JF	Bal MA
May - June	420 ≥	10.0		1					
July - Aug	0 ≥	4.0		-1	1				
Sep - Oct	0 ≥	-16.0			-1	1			
Nov - Dec	0 ≥		5.0			-1	1		
Jan - Feb	0 ≥		1.0				-1	1	
Mar - Apr	0 ≥		-7.0					-1	1

TABLE 13: METHOD B OF CAPITAL CONSTRUCTION FOR L.P.MATRIX (AFTER McFARQUHAR)

14.04 Both methods have the same imperfection. In the examples as shown, 30 pigs and 80 lambs could be kept, giving a margin of £140. However, if the year started in July, as in Table 14, instead of in May, as in Table 13, then the solution would be 105 pigs and 280 lambs giving a margin of £490. This occurs because revenue is available from pigs before they have been bought.

* It is assumed from McFarquhar's description that this is the construction used, since he does not illustrate this part of the matrix.

TABLE 14

Cost Row		2.0 1 Pig	1.0 1 Lamb	Bal JA	Bal SO	Bal ND	Bal JF	Bal MA	Bal MJ
July - Aug	420 ≥	4.0		1					
Sept - Oct	0 ≥	-16.0		-1	1				
Nov - Dec	0 ≥		5.0		-1	1			
Jan - Feb	0 ≥		1.0			-1	1		
Mar - Apr	0 ≥		-7.0				-1	1	
May - June	0 ≥	10.0						-1	1

TABLE 14: Method B of capital construction with year starting in July.

To correct this, another constraint is included to take cognisance of the amount of capital already invested in an enterprise at the start of the planning period. This has equivalence to the valuation of stock and crops paid for by an ingoing farmer, or the annual valuation of the assets of a business. The necessary modifications to the matrix in Table 14 would be:-

Cost Row		2.0 1 Pig	1.0 1 Lamb	Bal VC	Bal JA
Valuation Cap.	420 ≥	10*		1	
July - Aug.	0 ≥	4		-1	1

* The valuation of a pig is here taken to be purchase price + feed.

14.05 In the model used for this study, capital supply was treated as a variable rather than as a constraint because of the assumption (see Section 8.04) that there would be no limit on the availability of capital.

The Initial Capital variable had a cost coefficient of 9 per cent and therefore the type of construction illustrated in Tables 13 and 14 was used since this would allow interest to be paid on capital not used in any period, the Initial Capital supplied being sufficient for the peak cash requirement which will arise in one of the six periods.

If interest is paid on unused capital in any period, it must also increase the amount of money available in the next period, which renders the +1 and -1 type of matrix coefficients insufficient. Also, although total interest paid must balance total interest charged in the hypothetical case where a sum of Initial Capital is 'put through' the cash flow with no trading taking place, $i \neq I/n$ where 'i' = interest per period, 'I' = interest paid on Initial Capital and 'n' = number of periods.

14.06 Thus the matrix construction becomes as in Table 15.

TABLE 15

Cost Row		Z I.C.	0 Bal.VC	f Bal.JA	f . . . . f Bal.SO. . . Bal.n
Valn.Cap.	0 ≥	-1	1		
July - Aug	0 ≥		-1	r	
Sep - Oct	0 ≥			-1	r
n	0 ≥				. . . . r

TABLE 15: METHOD B WITH AMENDED MATRIX COEFFICIENTS.

and if a sum of money 'C' is made available as Initial Capital then:

$$Bn = C(1 + Z) \quad (1)$$

$$C \times Z = f(B_1 + B_2 \ldots\ldots + Bn) \quad (2)$$

where B_1 = value of first cash surplus variable, i.e. Bal.JA in Table 15

Bn = value of final cash surplus variable, i.e. Bal. n in Table 15

Z = interest rate for the Initial Capital variable

f = interest rate for each cash surplus variable

r = non-negative matrix coefficient.

From the construction of Table 15:

$$B_1 = C \times 1/r$$

$$B_2 = B_1 \times 1/r$$
$$= C\ (1/r)^2$$

$$Bn = C\ (1/r)^n$$

From (1)

$$Bn = C\ (1+Z)$$
$$C\ (1/r)^n = C\ (1 + Z)$$
$$1/r = \sqrt[n]{1 + Z}$$
$$r = \frac{1}{\sqrt[n]{1 + Z}}$$

Thus when $Z = 0.09$; $n = 6$ then $r = 0.98574$

From (2)

$$C \times Z = f\ (B_1 + B_2 \ldots\ldots\ldots + Bn\ )$$
$$= fC\ (1/r + 1/r^2 \ldots\ldots\ldots + 1/r^n)$$
$$f = Z\ /\ (1/r + 1/r^2 \ldots\ldots\ldots + 1/r^n)$$

Thus when $Z = 0.09$, $n = 6$ and $r = 0.98574$ then $f = 0.01426$

14.07 The matrix coefficients relating to capital requirements are, in the case of most variables, arrived at by simply distributing the factors making up the cost row entry, to the appropriate period as was demonstrated with pigs and lambs. There are three cases to be dealt with.

(1) That in which cash flows are spasmodic, and a whole production cycle is contained within one year from 1st March to 28th February e.g. sugar beet, early potatoes, barley growing (barley disposal is a separate enterprise).

(2) That in which there is a virtually continuous production process e.g. Dairying, barley beef production. Here it is assumed that one year of production is part of a continuous process already commenced, and that cash flows are regular. The cost of food, other than purchased concentrates, is not included in the enterprise margin, since the nutrient balances in the model allow other feed requirements to be met from farm production.

(3) That in which the production cycle is not contained within one year 1st March-28th February. e.g. Wheat growing, crops sold in spring (since a crop cannot be sold before it is grown), winter fattened cattle etc. The assumption made is that the year to which the model refers is the ith year in a series of n identical years, where $1 < i < n$. Thus if 10 tons of potatoes are to be sold in April there must be 10 tons of potatoes in store at 1st March and an input of capital is required. (see modification to <u>Table 14</u>). With the wheat crop, seed and fertiliser have already been paid for in respect of the current crop, and so cash to this value must be available on 1st March. In the case of winter fattened cattle, a store animal is bought in November at a cost of £72.10s. In February it is sold fat for £94, and is replaced by another store animal at £72.10.0d. Three out of five of the second batch of cattle are sold in April, and the remainder in May/June.

Thus, at 1st March this second animal is taken over at its net realisation value of £94 and the cash flow from winter fattened cattle becomes:

Valn. Capital 1 bullock @ £94	=	94.0
Period 1 Sell 0.6 @ £94	=	-56.4
Period 2 Sell 0.4 @ £94	=	-37.6
Period 3	=	0
Period 4	=	0
Period 5 Buy 1 @ £72.10s.	=	72.5
Period 6 Buy 1; sell 1 @ £94	=	-21.5

In the case of 18 month beef, the animal is bought in October and sold fat in April eighteen months later. Thus the stock on the farm at 1st March, per animal sold, is one calf of 4-5 months and one almost fat animal. The total value of these is taken as the estimated value of the calf (£35) plus the value of the fat animal (£77.9) less the calf subsidy of £9.75. Valuation capital is also required for the continuous production enterprises - dairying, and barley beef, - for sheep, since the breeding ewes are always on the farm, and for machinery.

For dairy enterprises, barley beef and sheep, the valuation capital is equivalent to the average value of the stock. For sheep this is the average of gimmers at £16 per head, and 4 yr. old ewes @ £8 per head. In the dairy enterprises the ingoing capital required is the average of heifers priced at £120 and cast cows at £70 with £100 addition for housing in the self-feed silage system and £90 for housing in the byre housed enterprise, since no dairy buildings are present on the farms. In the barley beef enterprises the value of stock per animal housed is the average of the value of a 200 lb. calf at £26.5.0d. and the fat animal at £75. When the stock is housed on slats, an additional

£13 per space is required to cover the conversion cost.

Farm machinery variables have been given a valuation capital requirement equivalent to the full purchase price of the equipment. The reason for this approach is that depreciation charges have no effect on the intrinsic worth of a machine, but are simply a mechanism to allow money to be retained for the future purchase of a replacement. Therefore if a machine is bought for £1000, and after three years is said to have a depreciated value of £520, then the balancing sum of £480 should in fact be held in reserve so that by selling the old machine, £1000 is available to replace it. Thus at any one time £1000 is tied up because of owning the machine. Enterprise capital requirements are detailed in <u>Appendix E.</u>

15.0 Labour planning in a Linear Programming Model

15.01 As with capital, the supply of labour in a linear programming matrix can be either a constraint, or, as in this model, a variable, and the accuracy of simulation may vary. The supply of labour and the demands of the various activities for labour may be expressed in terms of the whole year, or in such sub-divisions of the year as are considered desirable. A supply of overtime labour may be included with the supply of 'normal time' labour, in one combined supply coefficient, as was done by, for example, Wallace and Burr (21). Alternatively, overtime labour may be treated as a separate supply - see for example, Simpson (22 and 23).

Some allowance is normally made for the loss of working time due to weather unsuitable for outdoor operations, but usually no specific use is made of the 'lost' time. Consideration of the possibility of work falling behind may be included. To this end, McFarquhar (24) duplicates labour requirements where there are alternative times for carrying out an operation, while MacHardy (13) allows labour to be transferred from a later period in the year, at a cost penalty. In some cases (e.g. Simpson (22) p299; (23) p11) a specific time allowance is made for maintenance work, while in others (e.g. McFarquhar (24), p480) it is assumed that sufficient time will be available for this when the seasonal work load is small.

15.02 It is doubtful whether it is possible to exactly assess the proportion of time made unsuitable for field work because of weather conditions. Most publications which consider labour in relation to farm planning, make some allowance for time lost because of bad weather, but very often, the method of calculating the allowance is not defined. Wallace and Burr (21), for example, simply state that "Allowance has been made for bad weather ......" Belshaw and Scott (25) note that "...... the need to have some reserve for sickness, adverse weather conditions etc., must be borne in mind.", while McFarquhar (24) makes "...... an allowance for the possible reduction in this time available due to the effect of weather, illness, and so on".

Several publications do mention bases for weather loss deductions. Simpson (22) adds an arbitrary 5% to labour requirements for outside work, to cover the periods when such work is prevented by bad weather. Barnard and Weston (26) deduct 25% from total hours to allow for weather, illness, and essential maintenance. Tracey (27) makes an allowance of 6 weeks in the year for time lost due to bad weather. Simpson (23) estimates the time available for main operations from the rate of work and the capacity of key machines. None of these methods was used in time availability estimation for the present study, as it was felt that it should be possible to improve upon such arbitrary approximations.

15.03 There are several records of attempts to set values on weather parameters which might be used as criteria in deciding the probable availability of time for work on farm crops. It is generally recognised that the presence and intensity of a large number of factors - rainfall, relative humidity, wind, sunshine, temperature, frost, drainage - and the interaction of these, can affect the feasibility of farm operations. In addition, the effect of these factors will vary with different crops, and with the same crop at different stages of growth. It is also recognised that because of the difficulties of interpretation and application, it is desirable to evolve a method of estimating time loss which involves only two or three easily handled weather parameters.

Sitterley and Bere (28), estimating the number of days suitable for farm jobs in Ohio, took consideration of drainage rate, and of temperature, sunshine, windspeed, daily rainfall and accumulated rainfall as these affected evaporation and transpiration. For soil cultivations they suggest rates of water removal (= drainage + evaporation + transpiration) for good, average and poor drainage during spring and early summer. On the same basis drying rates in Autumn, in inches per day, are suggested for two qualities of drainage. For harvest work, days were classified according to dryness as good, fair or poor, assessment being based on rain, temperature, sunshine, wind and humidity. It is stated that most of the critical levels used are assumptions, and apart from the rates of soil water removal in spring and autumn, no specific data are given.

Smith (29), by comparing work records from East Midland farms, with meteorological records, developed detailed criteria relating rainfall to work feasibility in Spring for three grades of soil, and criteria for determining the frequency of periods suitable for grass drying. Smith's detailed criteria anent one soil type are shown in Appendix I.

The work of both Sitterley and Bere, and Smith, was thought to be unsuitable for application to the present study. That of Sitterley and Bere applies to conditions very different to those found in East Lothian, and the method of application is not described. That of Smith, although fully explained and pertinent to an area possibly not too different from East Lothian, unfortunately only applies to one season.

Methods of estimating working time loss due to weather were described in two studies carried out in the Edinburgh Area. MacHardy (13), from examination of the "Climatological Atlas of the British Isles", suggested that if 0.4" of rain, or more, fell in one day, then arable work would not be possible on that day or the following day, and that the presence of fog would stop cereal harvesting. Rennie (30) considered that only days on which less than 0.2" of rain fell were suitable for outside work, basing this decision on a comparison of rainfall records with the progress of work on an East Lothian farm. Again, neither of these suggestions was utilised. MacHardy's method was thought to be unrealistic, since practical experience indicated that much less than o.4" of rain could effectively stop arable work. Both methods took account only of precipitation, no attempt being made to allow for water removal, etc.

15.04 It was therefore decided to make a further attempt to estimate the critical levels of a small number of weather parameters, which could be easily used as criteria in deciding how much time would be available for arable work. This part of the study has been published (31), and is reproduced in Appendix J.

Using farm overtime records as an indicator of time loss it was concluded that a useful estimate of the number of days unsuitable for outside work could be obtained by discounting days on which the "State of Ground" recorded in Rainfall Station records was ≥ 2 i.e. "Wet (pools of water present)" or worse, or on which the rainfall was ≥ 0.1". The "State of Ground" estimation was recognised as being subjective and representative of a particular area only, but was utilised as being the result of the combination of several of the factors noted in Section 15.03.

That variations in the amount of time assumed to be provided by a worker can have a significant effect on farm profit is illustrated by Taggart (32) who compares the three margins obtained by planning the same farm with labour availability assumed to be affected by three slightly differing climates. This published work is reproduced in Appendix K.

15.05 In the construction of the model, normal working time was separated from overtime, since the first must be paid for whether or not it is utilised while the second is only utilised and paid for if it is necessary.

Also, both weather dependent time and wet time (i.e. Total available time minus weather dependent time) were included in the model, since it was thought that the time required for work which can be done in wet weather (e.g. potato dressing) could exceed the wet time available, if not constrained in this respect. Some previous linear programming models have constrained both weather dependent time and total time, but this is not satisfactory since it leads to error in balancing and charging for overtime use, as will be discussed in Section 15.06.

The year was divided, as shown in Table 16, into five periods approximating to the seasonal distribution of work on the farms as illustrated in Figure N.

TABLE 16

PERIOD	SEASON	FROM	TO
1	Spring	15th February	14th April
2	Early Summer	15th April	20th June
3	Summer	21st June	14th August
4	Harvest	15th August	18th November
5	Winter	19th November	14th February

TABLE 16: DIVISION OF THE YEAR INTO 5 PERIODS TO FIT SEASONAL WORK LIMITS.

The supply of labour was not regarded as a constraint, but as a variable to be introduced at a level appropriate to obtaining the maximum farm profit. This variable, representing one man employed for a year, supplies in each of the five seasons a calculated number of hours of Weather Dependent Normal Time (W.D.N.T.), Weather Dependent Overtime (W.D.O.T.), Wet Weather Normal Time (Wet N.T.) and Wet Weather Overtime (Wet O.T.). The seasonal labour requirements of the enterprises, in man hours per acre, were entered in the appropriate N.T. balances (Rows 8,10, 12,14,16,18,20,22,24).

Variables were included to allow N.T. balances to be supplemented by overtime work, at a cost of 7s. 5d. per hour, up to the limits set by the overtime balances (Rows 9,11,13,15,17,19,21,23,25), and two variables were included

FIGURE N

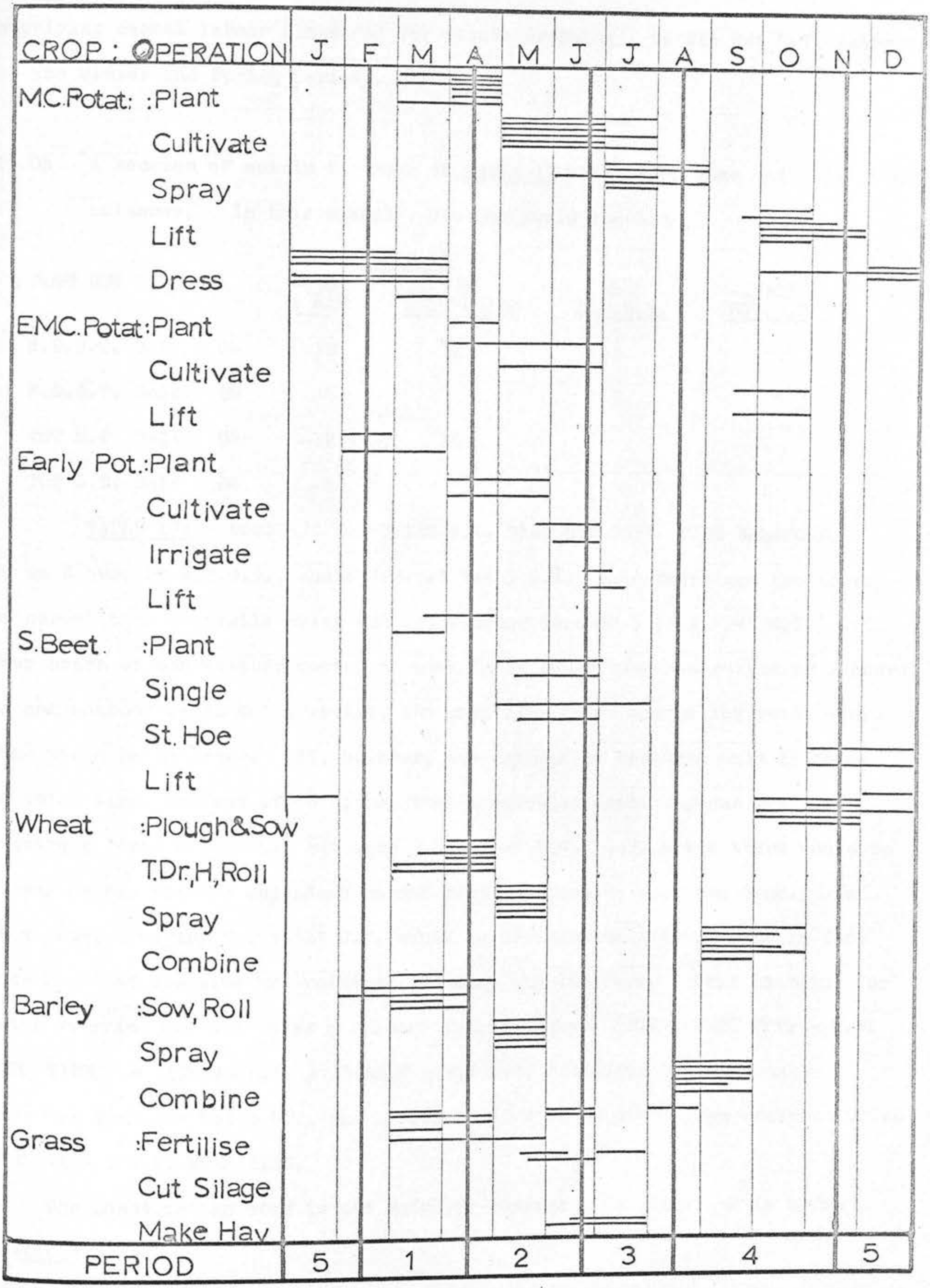


FIGURE N: SEASONAL WORK DISTRIBUTION AND WORK PERIODS.

supplying casual labour (intended for potato dressing), to the Wet N.T. balances in the Winter and Spring periods.

15.06 A section of matrix is shown in Table 17 using W.D. time and Total time balances. In this example, one man would require

TABLE 17

COST ROW		-750	50	0	-.3708
		1 MAN	ENTERPRISE	W.D.O.T.	TOT. OT
W.D.N.T. Bal:	0≥	-10	14	-1	
W.D.O.T. Bal:	0≥	-5		1	
TOT N.T. Bal:	0≥	-12	18		-1
TOT O.T. Bal:	0≥	-6			1

TABLE 17: CONSTRUCTION USING W.D. TIME AND TOTAL TIME BALANCES.

to do 4 Hrs. of W.D.O.T., and 6 Hrs. of Total O.T. Since there are two hours of normal time available which are not weather dependent (i.e. Wet N.T.) and four hours of non weather dependant work to be done, thus necessitating 2 hours of non weather dependent overtime, the case fits and a charge for Total overtime would be in order. If, however, the enterprise required only 15 hours of total time, instead of 18 hours, then a solution employing one man would require 4 hours of W.D.OT. but only 3 Hours of Total O.T. since there would be 1 hour of non weather dependant normal time in which no work was done. In this case, charging for total O.T. would be misrepresentative, since in fact four hours of overtime are required to carry out the work. Thus charging for total overtime can only give a correct solution where (TOTAL WORK TIME - W.D. WORK TIME) ≥ (TOTAL N.T. AVAILABLE - W.D.N.T. AVAILABLE). Obviously charging for both Total OT.. and W.D.OT. will give an overcharge wherever TOTAL WORK TIME > W.D. WORK TIME.

The construction used in the model to represent overtime use is shown in Table 18

TABLE 18

COST ROW		-750 IMAN	50 ENTERPRISE	-.3708 W.D.O.T.	-.3707 WET O.T.	0 SWOP
W.D.N.T. Bal:	0≧	-10	14	-1		1
W.D.O.T. Bal:	0≧	-5		1		
Wet N.T. Bal:	0≧	-2	4		-1	-1
Wet O.T. Bal:	0≧	-1			1	

TABLE 18: FORM OF LABOUR BALANCES USED IN MODEL.

The variable 'SWOP' could be dispensed with, without causing errors in overtime cost, but then work suitable for wet weather could be done only in wet weather, which is not the case in practice. The construction in Table 18 allows all W.D.N.T. to be used before any Wet O.T. has to be employed. The marginally lower charge for 'Wet O.T.' is a device to ensure that where both W.D.N.T. and Wet N.T. are fully used, wet weather work is extended into 'Wet O.T.' rather than W.D.O.T.

A constraint (Row 26) is included to limit the total overtime worked in a year, to 50% of the total possible overtime.

16.0 Selection of farm Machinery in the Model

16.01 The cost of owning and running farm machinery is often regarded in budgeting as a 'fixed cost', but this is only true in relation to marginal changes in organisation. When complete re-planning is undertaken, there are the options of avoiding this cost, or of incurring it at various levels. Some machines, such as tractors, are used for a wide variety of work, while others, such as potato harvesters, are used only for specific enterprises and their cost must therefore have an influence on the choice of enterprises, and on the levels of activity chosen.

The cost of machinery is taken to consist of depreciation, repairs, and for tractors, fuel. Repairs can normally be regarded as a function of the amount of work done by the machine. Depreciation only involves actual cash outlay when a machine is replaced, although it is normal accounting procedure to deduct annually from the profit a proportion of the net replacement cost. The total depreciation charge on a machine is the difference between its purchase price and its realisation value at disposal. When it is necessary to assess the value of a machine at a particular time, various methods may be used to apportion the depreciation charge over a series of years. (See for example Haythorne (33)). Since in this case the model is intended to represent any one of a series of identical years, no real improvement can be made on the assumption that annual depreciation = V/n, where 'V' = new value, and 'n' = length of life in years. The length of life of a machine will vary with the type of work performed, the annual work load, the number of moving parts, and the type of machine, as this affects obsolescence. For the sake of continuity it was decided to base estimates of repair costs and depreciation on the relationships suggested by Culpin (5) and shown in Figure I and Table 7, Section 9.02.

16.02 In the earlier models constructed, an almost complete range of the moveable equipment required to handle the crops considered, was included. Twenty variables were required, as listed in Table 19.

TABLE 19

IMPLEMENT	TYPE	NEW COST (£)	IMPLEMENT	TYPE	NEW COST(£)
Tractor	MF 165	1035 *	Sprayer	18'	140
Plough	2 x 14"	115	Steerage Hoe	5 drill	120
Rotavator	5'	350	Mower + Tedder	5'	255
Triple K	7'	53	For.Harv.	60"	376 *
Harrows	18'	47	Baler + Stacker	Mc.C.B.47	758 *
Roller	24'	300	Pot.Harv.	1 row	860 *
Pot.Planter	4 drill	405 *	Comb.Harv.	M.788	2040 *
Grain Drill	12'	440	Beet Harv.	Lister	470 *
Beet Seeder	5 drill	206	Pot.Dresser	Couch	850 *
Fert. Dist.	18'	135			
Ridger	5 drill	67			

* These items only are included in later models (See Table 21)

TABLE 19 EQUIPMENT VARIABLES INCLUDED IN EARLY MODEL.

Since many of these implements are common to several cropping enterprises and also have low annual costs in relation to their normal work capacities, it was thought that to leave some of them out of the model might not greatly affect the solution. This would also reduce the size of the matrix, increasing the chance of a particular problem being within the capacity of the K.D.F. 9 computer (See Section 13.05), and saving computer time. To test this thesis, the same farm planning problem was solved twice. The first run (A) included all the equipment listed in Table 19 while the second version (B) included only eight items. The identical solutions to these problems which are summarised in Table 20 were considered to justify the inclusion of only seven of the more expensive and more enterprise specific machines, in addition to tractors, in the final model.

TABLE 20

Optimal solutions obtained for a farm organisation problem with (A) Selection from 20 equipment variables (B) Selection reduced to 8 machinery variables.

BASIC VARIABLES	BASIC VARIABLE VALUES	
	SOLUTION A	SOLUTION B
Objective Function	18,169.4	18,920.1
Tractor + Trailer	6.62	6.14
Ploughs	2.45	Not Included
Rotavators	1.37	"
Triple K	1.55	"
Harrows	0.42	"
Rollers	0.53	"
Potato Planters	1.02	1.02
Grain Drills	0.64	Not Included
Beet Seeders	0.40	Not Included
Fertiliser Distributors	0.59	"
Ridgers	2.05	"
Sprayers	0.57	"
Steerage Hoes	0.90	"
Mower + Turner	0.02	"
Forage Harvester	0.03	0.03
Baler + Stacker	0.56	0.56

TABLE 20 (Cont.)

BASIC VARIABLES	BASIC VARIABLE VALUES SOLUTION A	SOLUTION B
Potato Harvesters	0.90	0.90
Combine Harvesters	0.86	0.86
Beet Harvesters	0.48	0.48
Potato Dressers	0.39	0.39
F.Y.M. Spread 17/8-18/11 Tons.	1090.0	1090.0
Cows on Self Fed Silage	8.1	8.1
Cows on Mixed Feed	170.33	170.33
Silage (2 Cuts)	3.78	3.78
Tower Silo (Cu. Ft.)	5060	5060
Soya Meal Fed (Tons)	29.19	29.19
Barley Fed	179.3	179.3
Beet Tops Fed	362.9	362.9
Straw Fed	166.5	166.5
Straw for litter	170.3	170.3
Potatoes sold in Autumn	158.3	158.3
Potatoes sold in Spring	94.1	94.1
Wheat sold in Spring	212.9	212.9
HEAVY LAND CROPS		
Maincrop potatoes	28.0	28.0
Wheat	70.0	70.0
Grass	3.78	3.78
Irrigated Grazing	38.22	38.22
MEDIUM LAND CROPS		
Early Maincrop Potatoes	31.47	31.47
Second Early Potatoes	49.71	49.71
Sugar Beet	48.39	48.39
Wheat	32.96	32.96
Barley	112.47	112.47

BASIC VARIABLES	BASIC VARIABLE VALUES	
	SOLUTION A	SOLUTION B
LIGHT LAND CROPS		
Second Early Potatoes	34.00	34.00
Irrigated Grazing	51.00	51.00

TABLE 20: COMPARATIVE SOLUTIONS: (A) 20 EQUIPMENT VARIABLES
(B) 8 EQUIPMENT VARIABLES

16.03 Although it was not thought to distort the solution too much if acreages, livestock numbers and other variables which either have relatively large values, or are divisible, were left in non-integer form, the case of implements and of men is different. In these cases the variables represent indivisible units which enter the solution in quantities such that a fractional part can be an appreciable proportion of the entire value of the variable.

Therefore if possible selection of integer values of men and machines should be induced.

It is possible, in linear programming, to induce either complete or partial integer forms of solution by adding to a first, non integer solution, further constraints calculated to force the solution into integer form. See for example Dantzig (11), Edwards (34), Camm and Röthlisberger (35).

This is not satisfactory in the case of farm machines since the annual cost of running, say, a combined harvester, will depend on the acreage of cereals harvested, and therefore to force the selection of a whole combine achieves nothing, if the cost factor is not consistent with the amount of work performed.

A similar method to that suggested by MacHardy (13) was therefore used. In this, a probable or possible cropping plan for the problem farm is first estimated. This gives the required annual work capacity, in acres or tons, of each type of machine, and the level of repairs and depreciation can then be calculated. The figures for machine capacity (Rows 31-38) and annual cost are then inserted in the matrix, and the problem is solved. If the cropping in this solution co-incides with the estimated cropping, then the machines selected will have integer values, and the problem has been solved in one stage.

Usually, however, there are variations between the two plans which lead to non-integer machine values in the first computed solution. In this case, the crop acreages in the first solution are used to re-assess machine capacities and annual costs, and these are used as coefficients in a second attempt. Very often the second solution is only marginally different from the first, so giving a plan which has included consideration of the effect of machinery requirements, and which includes these machines in whole units with annual costs appropriate to the work carried out. If necessary, adjustment and computation can be repeated until a satisfactory solution is obtained.

16.04 This technique can be extended to ensure that a sufficient number of men is selected to supply any size of work team which may be necessary, and to induce the selection of an integer number of men. Constraints are included (Rows 27-30) which specify minimum work team sizes for each machine. Thus, if the man-hour seasonal balances (Section 15.05) used alone would lead to the selection of 7.37 men in a particular problem, then if the selection of exactly two potato harvesters, each with a team size of four men, was induced as described above, so would the selection of eight men be forced.

16.05 The type of result obtained by this procedure is illustrated by programmes run for a 403 acre farm on Medium-Heavy land. For the first run (K3), notional implement capacity coefficients were based on the acreages worked by machines fairly fully occupied. Cost row coefficients and cash balance entries for repairs and depreciation were calculated from the relationships suggested by Culpin (Section 9.02). Using these coefficients, as shown in Table 21, the solution given in Table 22(K3) was obtained.

TABLE 21

IMPLEMENT	CAPACITY	REPAIRS £/Year	DEPR. £/Yr.	ANN. COST £/Yr.	WORK TEAM
Tractor + Trailer	1 per man	155.25*	168	397.375	
Potato Planter	140 ac. (All pot.)	23.7	38.5	62.2	6
Forage Harvester	120 ac.	18.0	39.2	57.2	5
Baler + Loader	500 T. (Hay + Straw)	22.8	63.3	86.1	4)
Combine Harvester	250 ac.	90.3	193.5	283.8	+ 2)
Potato Harvester	50 Ac. (MC + 2/3 EMC).	150.5	195.5	346.0	5
Beet Harvester	60 Ac.	35.3	64.5	99.8	
Potato Dresser (1) Potato Dresser (2)	700T (MC)) 96 Ac. (EMC))	20.1	129.1	149.2	

TABLE 21: MACHINE CAPACITIES AND COSTS FOR PROGRAM K3.

TABLE 22

VARIABLE	SOLUTION K3	SOLUTION K4
Farm Margin	£10,779	£10,376
Initial Capital	43,541	45,536
Early M.C. Potatoes	100.75 ac.	100.75 ac.
Sugar Beet	77.74 ac.	83.89 ac.
Wheat	100.75 ac.	100.75 ac.
Barley	123.76 ac.	117.61 ac.
Straw Fed.	18.4 T.	
Straw Litter	12.2 T.	6.8 T.
Bar. beef (Slats)	213.2	236.4
Winter Cattle	13.04	7.25
Pigs	52.2	29.0
Ewes	50.0	50.0
Men + Tractors	6.72	7.00
Potato Planters	0.72	1.00
Balers + Stackers	0.06	0.22
Potato Harvesters	1.34	2.00
Combine Harvesters	0.90	0.97
Beet Harvesters	1.30	2.16
Potato dressers	1.05	1.00

TABLE 22: SOLUTIONS TO PROGRAMS K3 AND K4 - INDUCEMENT OF NEAR INTEGER VALUES OF MACHINES AND MEN.

* Includes fuel

From Solution K3., machine capacities and costs were recalculated as shown in Table 23, substituted in the problem data for those in Table 21, and the program was re-run to obtain Solution K4 in Table 22.

TABLE 23

IMPLEMENT	EXPECTED NUMBER	CAPACITY	REPAIRS £/Yr.	DEPR. £/Yr.	ANNL. COST	TEAM
Tractor + Trailer	7	1 per man	155.25*	168	397.375	
Potato Planter	1	100.75 ac.	17.0	34.7	51.7	6
Forage Harvester	0	40 (Nominal)	7.5	33.5	41.0	5
Baler + Bale loader	1	30.6 Tons	2.3	47.4	49.7	4) +)
Combine Harvester	2	224.51 ac.	84.3	185.2	269.5	2)
Potato Harvester	1	33.58 ac.	101.0	155.0	256.0	$3\frac{1}{2}$ *
Sugar Beet Harvester	2	38.87	22.7	54.2	76.9	
Potato Dresser (1)	1	700T (M.C.))	55.0	129.4	184.4	
Potato Dresser (2)		100.75 ac(EMC))				

TABLE 23: RECALCULATED MACHINERY CAPACITIES AND COSTS, BASED ON SOLUTION K3.

* For Program K4 the squad size requirement for potato harvesters was altered from 5 men to $3\frac{1}{2}$ men. This was done only after consideration of conditions on the farm, which is compact.

Solution K4 could possibly be improved by a third attempt. If this were done, it is probable that balers, straw, winter cattle, and pigs would be left out completely, the number of barley beef cattle increasing. Sugar beet might increase slightly further, with a compensatory reduction in the barley acreage. Any further shifts in enterprise size, however, are likely to be marginal. Solution K4 is therefore, accepted as the optimal organisation for this farm.

* Includes fuel

16.06 This process was used in obtaining an optimal plan for each of the six farms. In planning the organisation of the 2811 acre amalgamated unit, the linear programming model was first used to arrive at an optimal plan using machinery of the same type and size as that used on the individual farms, by the method which has been described. A gang-work chart was then drafted illustrating the deployment of men and machines throughout the year to carry out the necessary work. The effect of substituting large high capacity machines for the original types was then examined by drafting a further gang-work chart in which the large machines were used to carry out the same work, using bigger teams of men per machine but leading to an overall reduction in the number of men required. This procedure is fully described in Section 20.0.

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RESULTS

17.0 Stages of Comparison

17.01 The proposed comparison of results outlined in Section 8.05 may now be re-stated in the sequence in which it is intended to present those results.

(a) Present farming systems. Farm Margins, Labour force, capital, etc. calculated using standard data (Stage I)

(b) Optimal plans for each farm, including dairying.

(c) Optimal plan for the amalgamated unit, including dairying.

(d) Comparison of (a), (b) and (c).

(e) Optimal plans for each farm limited to Stage I capital - no dairying.

(f) Optimal plans for each farm with no capital limit and no dairying (Stage II).

(g) Comparison of (a), (e) and (f).

(h) Optimal plan for the amalgamated unit; no capital limit, no dairying (Stage III)

(i) Stage III adjusted for effect of large machinery (Stage IV)

(j) Comparison of (a), (f), and (i).

PART THREE

RESULTS OF THE INVESTIGATION

17.02 (a) STAGE I To obtain this, standard input-output data (See Sections 8.02, 9.01, 9.02, Table 6, and Appendices B, C, D and E) were applied to the acreages of various crops and the numbers of different types of stock normal to each farm in 1965. This produced a calculated size of farm staff and machine complement, and a calculated farm margin and capital requirement, and forms the basis for measuring the effect of further planned changes in the organisation and structure of the farms. These results are summarised in Table 24.

17.03 (b) The organisation planned for each farm when dairying is included as a feasible enterprise. Two types of dairy enterprise were included in the model:

(1) COWS (SF) Winter feeding is based on 96lb/day (9 Tons/Cow/210 day winter) of 12% SE Silage, self fed. The cows are loose housed.

(2) COWS (BYRE) Winter rations are selected as part of the problem. Since with a large amount of arable by-products available this might be a mixed diet, provision is made for byre housing.

TABLE 24

VARIABLE	F1	F2	F3	F4	F5	F6	TOTAL
M. Crop	50	91	63	30	30	76	355
R.Skin	10			20	20		50
2E	10			50			60
1E	15			50			65
S.Beet	50			50			100
Wheat	128	150	120	220	110	62	790
Barley	115	211	200	80	375	140	1121
Grass	60	90			35	45	230
Roots	5		20		10	5	40
B.Beef		240	200		153	200	793
Cattle	150	212			53		415
Sheep	70					380	450
Silage	55	78.0					133
Hay					13	10	23
Men	6	9	5	6	8	5	39
Pot. Pl.	1	1	1	1	1	1	6
F.Hv.	1	1					2
Baler	1	1			1	1	4
Pot.Hv.	2	2	1	2	2	1	10
Combines	1	2	2	1	2	1	9
Bt.Hv.	1			1			2
Pot.Dress	1	1	1	1	1	1	6
Init.Cap.	33027	60293	29532	26364	37544	27206	213966
Margin	11136	9270	6506	13450	8210	1300	49872
I.C/Ac.	74.6	111.2	73.3	52.7	60.0	91.6	76.1
M/Ac.	25.3	17.1	16.1	26.9	13.1	4.4	17.8
100 M/IC	33.9	15.4	22.0	51.0	21.9	4.8	23.3

TABLE 24(a) STAGE I - PRESENT FARM SYSTEMS

For both types of dairy enterprise, housing must be erected, which affects the Initial Capital for these enterprises, and also their cash flows and cost row entries. Dairy labour is charged directly to the dairying activities and is not included in the Labour section of the model.

Summaries of the solutions to these programs are shown in Table 25. No effort was made to induce integer values for men and machines in these solutions.

17.04 (c) The whole unit of 2811 acres was planned for farming as one business, again including the two dairy enterprises in the list of feasible enterprises. Both (b) and (c) are arrived at by using Linear Programming and a modification of the model described in Sections 13.0 to 16.0 to compute optimal plans from the standard data.

The modifications involved: Subdividing Heavy, Medium-Heavy, Medium and Light land types according to the acres of each type on which irrigation was possible. Because it was expected that the solution would include a fairly large number of cows on irrigated grazing on F1 and F4 and that little silage grass would be grown on F1/F4, a labour penalty was introduced for silage grown elsewhere, to allow for transport time to F1/F4. The labour penalty was based on the assumption that an acre of grass cut twice for silage would involve the transportation of 21.4 tons of fresh grass at 2 Tons per trailer load at 15 m.p.h. - i.e. 42.8 minutes per acre/mile. It was assumed that half the grass would go to F1 and half to F4, and the distances to these farms from each of the others was adjusted by a factor based on the size of each farm to arrive at an overall average of 6.07 acre miles per acre of silage. The labour penalty of 4.3 hours of W.D. time per acre of silage was divided between the two cutting seasons and applied to silage made elsewhere than on F1 and F4.

The computed optimal plan for the 2811 acre unit is summarised in Table 26.

TABLE 25

VARIABLE	F1	F2	F3	F4	F5	F6	TOTAL
M. Crop	13.5	12.2	3.8	28.0	6.7	9.7	73.9
R.Skin	64.0	90.3	96.0	31.5	123.2	5.0	410.0
2E	26.6			83.7			110.3
1E							
S.Beet	47.9	58.1	84.1	48.4	57.7	6.7	302.9
Wheat	87.4	211.1	144.8	102.9	271.7	80.9	898.8
Barley	118.6	49.4	29.3	112.5	51.4	118.8	480.0
Grass		120.9	45.0	3.8	115.3	75.9	360.9
Irr. Gr.	85.0			89.2			174.2
Cows (SF)		69.7	25.1	8.1	64.9	48.1	215.9
Cows (Byre)	170.1		6.0	170.3			346.4
B.Beef	345.0	409.4	89.2		324.3	180.7	1348.6
Other Cattle		60.4	44.0		71.9	13.3	189.6
Grazing		53.5	19.8		46.0	13.2	132.5
Silage		63.3	25.2		54.6	48.4	191.5
Hay						4.1	4.1
Men	5.19	7.03	6.58	6.14	8.32	2.01	35.27
Pot. Pl.	0.74	0.73	0.71	1.02	0.93	0.11	4.24
F. Hv.		0.56	0.21	0.03	0.51	0.40	1.71
Balv.	0.53	0.25	0.17	0.56	0.27	0.10	1.88
Pot. Hv.	1.04	1.41	1.32	0.90	1.66	0.25	6.58
Comb.	0.82	1.04	0.70	0.86	1.29	0.80	5.51
Bt. Hv.	0.48	0.47	0.67	0.48	0.57	0.05	2.72
P. Dress	0.67	0.94	1.01	0.39	1.28	0.14	4.43
In. Cap.	67198	74222	36123	53275	73274	34236	338328
Margin	18698	15633	10805	18920	17809	5964	87829
IC/Ac.	151.7	137.0	89.6	106.6	117.1	115.3	120.4
M/Ac.	42.2	28.8	26.8	37.8	28.4	20.1	31.2
100 M/IC	27.8	21.1	29.9	35.5	24.3	17.4	25.9

TABLE 25:(b) OPTIMAL FARM SYSTEMS, INCLUDING DAIRYING.

TABLE 26

VARIABLE	VALUE	VARIABLE	VALUE
M. Crop	59.8	Men	31.72
R. Skin	409.0	Pot. Pl.	4.43
2E	151.4	F. Hv.	1.90
1E		Baler	2.07
S. Beet	223.3	Pot. Hv.	6.34
Wheat	809.6	Combine	5.42
Barley	544.6	Bt. Hv.	2.22
Grass	261.8	P. Dress	4.26
Irr. Gr.	351.5	Init. Cap.	403441
Cows (SF)	379.4	Margin	101525
Cows (Byre)	400.0	IC/Ac.	143.5
B. Beef	1945.9	M/Ac.	36.1
Grazing	12.6	100M/I.C.	25.2
Silage	228.0		

TABLE 26:(c) OPTIMAL SYSTEM FOR AMALGAMATED UNIT, INCLUDING DAIRYING

17.05 (d) These three sets of results are compared in Table 27 to illustrate the effect of, and the potential increase in profitability from, the introduction of dairying to the arable farm system, and the subsequent amalgamation of these farms. This branch of the investigation was not taken beyond the stage of exploratory calculations, in that solutions were left in non-integer form, and the effect of large machinery was not investigated.

TABLE 27

VARIABLE	(a) TOTAL FOR SIX ON PRESENT SYSTEM		(b) TOTAL FOR SIX DAIRYING-OPTIMAL		(c) COMBINED UNIT DAIRYING-OPTIMAL	
	AC.	%	AC.	%	AC.	%
M.C. + R.Sk.	405)	18.8	484)	21.1	469)	22.1
Early Potat.	125)		110)		151)	
S.Beet/Roots	140	5.0	303	10.8	223	7.9
Wheat	790)	68.0	899)	49.1	810)	48.2
Barley	1121)		480)		545)	
Grass	230)	8.2	361)	19.0	262)	21.8
Irrig.Graze			174		351)	
Cows (SF)			216		379	
Cows (Byre)			346		400	
Barley Beef	793		1349		1946	
Other Cattle	415		190			
Sheep	450					
Grazing	74		133		13	
Silage + Hay	156		196		228	
Men	39		35.27		31.72	
Pot Planters	6		4.24		4.43	
Forage Harv.	2		1.71		1.90	
Balers	4		1.88		2.07	
Pot. Harvs.	10		6.58		6.34	
Combines	9		5.51		5.42	
Beet Harvs.	2		2.72		2.22	
Pot. Dressers	6		4.43		4.26	
Initial Cap.	213966		338328		403441	
Margin	49872		87829		101525	
IC/Ac.	76.12		120.4		143.5	
M/Ac.	17.77		31.2		36.1	
100 M/IC	23.34		25.9		25.2	

TABLE 27: COMPARATIVE SUMMARY OF CROP, STOCK AND FINANCE FOR SIX FARMS UNDER THREE SYSTEMS OF FARMING. (a),(b),(c).

17.06 The comparisons shown in Tables 24 + 25 suggests that dairying is an attractive enterprise on arable farms. The result of re-planning the individual farms is, in general, to substitute grass for barley, with potatoes being increased except on two farms, sugar beet being maintained or introduced and wheat being increased in some cases and reduced in others, but with an overall increase.

There are four points of particular interest.

(a) Potatoes have been greatly reduced on the smallest farm, which due to the distribution of soil types has a smaller potential acreage and lower average yield. The inference is that on this farm the potato output is not sufficient to justify the men and machinery required, nor is there sufficient work on other enterprises to justify the size of staff required to handle potatoes.

(b) Sugar beet has been introduced on the four farms which in 1965 did not grow this crop. Two of these farms (F2 and F5) had previously grown sugar beet but had stopped, partly because enterprise costs published for sugar beet on East Lothian farms had shown the crop to be unprofitable. Farmer F2 commented on the effect of dropping sugar beet - "Since we went out of sugar beet things have been much easier, with more time for odd jobs, but I miss the sugar beet money at the end of the year. My labour bill has gone down slightly, but not very much."

(c) The main introduction of dairy cows on individual farms was on F1 and F4, the two farms which can irrigate grazing land. On each of these, program solutions indicate herds of 170 cows wintered on arable by-products. On the other farms, herds introduced range from 31 to 70 cows, winter feeding being almost entirely self-fed silage.

(d) The number of barley beef cattle carried increased by 70% from 793 to 1349, the larger number being carried entirely on slats while 75% of the 793 cattle carried in 1965 were on straw.

The effect of replanning the farms with the introduction of dairying was to increase the farm margin by 141%-459% (overall 176%) and to increase the capital needed by 122%-203% (overall 158%). In any comparison of 'present' with 'optimum' for individual farms it should be remembered that the relatively low level of margin attained under the present systems must be qualified by three factors:

1. The decisions leading to the present systems were made using somewhat different information and assumptions to those used in producing the optimal plans.
2. In spite of assurances that capital could be obtained for any worthwhile expansion of a farm business of this type, it may be more limiting than is publicly admitted.
3. The combined factors of risk, need, and tax penalty. i.e. As gross income rises, need for marginal income decreases, and because of tax the marginal net income per £1 earned decreases. These together rapidly reduce the level of risk which is acceptable, and with a biological system and a fixed level of management ability, intensification of the business rapidly increases the risk involved.

In that the individual optimal systems (Table 25 and Col.2, Table 27) are based on the same data and have the same freedom from capital restraint as the optimal system for the amalgamated unit, they are unaffected by the factors discussed in (1) (2) and (3) above, and therefore a comparison of the results in Tables 25 and 26 (Cols. 2 and 3, Table 27) will give a more accurate indication of the effect of the amalgamation of these farms than would a comparison of the results in Tables 24 and 26 (Cols. 1 and 3, Table 27).

It is possible that a group of farmers would be willing to accept a higher level of risk than the average level they would accept as individuals; also, because of the greater diversification economically possible due to the larger size of business, it would be possible to undertake a greater proportion of high risk (and high margin) enterprises without increasing the overall risk. The question of whether to accept the statement by the farmers that they as individuals are not subject to capital limitations, or to accept the possibly cynical view expressed in Section 17.06 (2) of this thesis, can only be resolved by a practical test, which was not possible. If it is accepted that the level of risk taken by individuals is less than that taken by a group composed of those individuals, and that amalgamation would allow access to a greater amount of capital, then the effect of amalgamation is best measured by the comparison of the results in Tables 24 and 26 (Cols. 1 and 3, Table 27).

Since the measurement of risk and the attitude of people to risk in business is beyond the scope of this thesis and the effect of capital limitation is further discussed in Section 18.0, the change in system shown in Cols. 2 and 3 of Table 27 is taken to indicate the effect of amalgamation when dairying is an acceptable enterprise. The main change involves a 39% increase in dairy cow numbers, and an almost complete dependence on the irrigated grazing on F1 and F4 for summer pasture, winter feed being silage for 379 cows and a mixed diet for 400 cows. Since all grass on F1 and F4 is used for grazing, all silage is grown on other parts of the 'farm'. There is also a 44% increase in the number of Barley Beef animals carried. Other changes in system are relatively small - 4% increase (26 ac.) in potatoes; 36% decrease (80 ac.) in sugar beet; 2% decrease (24 ac.) in cereals with a slight swing to barley; 10% decrease (3.55 men) in the size of the general farm staff, apart from dairymen. The farm margin, however, increased by 15.6% (£13,696) with an increase of 19.2% (£65,113) in the capital required.

When these results were discussed with the group, two (F1 and F4) were in favour of large scale commercial dairy farming; two (F5 and F6) would undertake dairying if they were farming purely for profit although F6 was more in favour of barley beef as a means of intensification; two were against dairying - mainly because they preferred arable farming and did not find the pressure sufficient to make them become involved in year round livestock.

It was decided that in further investigation, dairying should not be brought into consideration.

18.0 Effects of Capital Limitation

18.01 As has been previously discussed, the planning of the amalgamated unit of 2811 acres includes the assumption that it is unnecessary to limit the availability of tenants' capital. Due to doubt as to the validity of the co-operating farmers' claim to be free of capital limitation as individuals ((2) P.135), and also because the effect of individual abilities and objectives upon a business ((1) P.135, (3) P.135), this raises the question of what the result of planning an amalgamated farm should be compared with in order to assess the potential advantage or disadvantage of amalgamation. In order to define the effect of capital availability on the organisation of the farms, two series of plans for the individual farms were computed - one (e) imposing as constraints the amounts of initial capital already calculated as being required for the STAGE I (1965 Present) systems, and the other (f) having no capital limitation. Tables 28(1) to 28(6) compare the results obtained. Each table refers to one farm and shows three systems - (a) the Stage I system, with financial results calculated from standard data (See also Table 24) - (e) the optimal system when capital is limited to the Stage I amount - (f) the optimal system when capital is not limited, which is also referred to as STAGE II.

For Farm F6 no 'limited capital' solution was calculated, since the amount of capital used with no limitation was only £128 (0.47%) greater than the £27,206 calculated for Stage I.

TABLE 28 (1)

Variable	(a) Stage I System	OPTIMAL SYSTEMS	
		Lim. Cap. (e)	Cap. not Lim.(f)
Potatoes - Main Crop	50	17.1	
" - Redskin	10	41.4	78.2
" - Early	25	33.9	30.0
Sugar Beet	50	71.1	89.3
Wheat	128	134.3	137.9
Barley	115	137.2	99.6
Grass	60	8.0	8.0
Other Crops	5		
Barley Beef Cattle		126.7	526.1
Other Cattle	150	40.8	28.5
Sheep	70		
Pigs Fattened		177.1	90.2
Men	6	6.53	7.00
Potato Planters	1	0.94	1.00
Forage Harvesters	1		
Balers	1	1.13	0.53
Potato Harvesters	2	1.87	2.00
Combine "	1	1.01	0.94
Beet "	1	2.09	2.35
Potato Dressers	1	0.94	1.00
Initial Capital	33027	33027	55679
Margin	11136	11756	15091
IC/Ac.	74.6	74.6	125.7
M/Ac.	25.1	26.5	34.1
100 M/IC	33.7	35.6	26.9

TABLE 28 (1): EFFECT ON F1 SYSTEM OF RE-PLANNING WITH LIMITED AND UNLIMITED CAPITAL AVAILABILITY.

TABLE 28 (2)

Variable	(a) Stage I System	Optimal System	
		Lim. Cap. (e)	Cap. not Lim.(f)
Potatoes - Main Crop	91	18.2	
" - Redskin		40.1	90.3
" - Earlies			
Sugar Beet		13.9	58.3
Wheat	150	94.5	125.2
Barley	211	339.1	232.0
Grass	90	36.2	36.2
Other			
Barley Beef	240	648.8	712.6
Other Cattle	212	55.0	76.4
Sheep			
Pigs		72.8	212.8
Men	9	5.83	8
Potato Planters	1	0.97	1.00
Forage Harvesters	1		
Balers	1	0.41	1.07
Potato Harvesters	2	1.12	2.00
Combine "	2	2.09	1.87
Beet "		0.46	1.79
Pot. Dressers	1	0.67	1.00
Initial Capital	60293	60293	73134
Margin	9270	13168	14993
IC/Ac.	111.2	111.2	134.9
M/Ac.	17.1	24.3	27.7
100 M/IC	15.4	21.8	20.5

TABLE 28 (2): EFFECT ON F2 SYSTEM OF RE-PLANNING WITH LIMITED AND UNLIMITED CAPITAL AVAILABILITY.

TABLE 28 (3)

Variable	(a) Stage I System	Optimal System	
		Lim. Cap.(e)	Cap. not Lim.(f)
Potatoes - Main Crop	63	15.0	
Potatoes - Redskin		34.8	100.8
" - Earlies			
Sugar Beet		28.5	83.8
Wheat	120	53.6	100.8
Barley	200	266.0	117.6
Grass		5.1	
Other	20		
Barley Beef	200	176.3	236.4
Other Cattle		14.6	7.3
Sheep			50.0
Pigs		21.4	29.0
Men	5	4.69	7.00
Potato Planters	1	0.78	1.00
Forage Harvesters		0.12	
Balers		0.02	0.22
Potato Harvesters	1	0.89	2.00
Combine "	2	1.99	0.97
Beet "		1.70	2.16
Potato Dressers	1	0.55	1.00
Initial Capital	29532	29532	45536
Margin	6506	7314	10376
IC/Ac.	73.3	73.3	113.0
M/Ac.	16.1	18.1	25.8
100 M/IC	22.0	24.8	22.7

TABLE 28 (3): EFFECT ON F3 SYSTEM OF RE-PLANNING WITH LIMITED AND UNLIMITED CAPITAL AVAILABILITY.

TABLE 28 (4)

Variable	(a) Stage I System	Optimal System	
		Lim. Cap.(e)	Cap. not Lim.(f)
Potatoes - Main Crop	30	19.5	28.0
Potatoes - Redskin	20	51.9	63.2
Potatoes - Earlies	100	31.8	41.4
Sugar Beet	50	88.1	105.5
Wheat	220	163.1	177.9
Barley	80	123.6	56.0
Grass		22.0	28.0
Other Crops			
Barley Beef			
Other Cattle			10.5
Sheep		63.2	81.0
Pigs			
Men	6	6.20	6.73
Potato Planters	1	0.89	1.11
Forage Harvesters			
Balers			
Potato Harvesters	2	1.77	1.92
Combine "	1	0.99	0.86
Beet "	1	2.22	2.18
Potato Dressers	1	0.92	1.04
Initial Capital	26364	26364	29425
Margin	13450	11946	13060
IC/Ac.	52.7	52.7	58.9
M/Ac.	26.9	23.9	26.1
100 M/IC	51.0	45.3	44.3

TABLE 28 (4): EFFECT ON F4 SYSTEM OF RE-PLANNING WITH LIMITED AND UNLIMITED CAPITAL AVAILABILITY.

TABLE 28 (5)

Variable	(a) Stage I System	Optimal System	
		Lim. Cap. (e)	Cap. not Lim.(f)
Potatoes - Main Crop	76		
Potatoes - Redskin	20	82.9	131.5
Potatoes - Earlies			
Sugar Beet		38.5	68.4
Wheat	110	112.0	183.2
Barley	375	367.6	217.9
Grass	35	25.0	25.0
Other Crops	10		
Barley Beef	153	159.5	622.8
Other Cattle	53	18.6	64.9
Sheep			
Pigs		74.4	166.8
Men	8	6.66	9.00
Potato Planters	1	0.75	1.00
Forage Harvesters			
Balers	1	0.54	1.29
Potato Harvesters	2	1.48	2.00
Combine Harvesters	2	2.26	1.92
Beet "		0.58	1.23
Potato Dressers	1	1.50	2.00
Initial Capital	37544	37544	70678
Margin	8210	11169	17482
IC/Ac.	60.0	60.0	112.9
M/Ac.	13.1	17.8	27.9
100 M/IC	21.9	29.7	24.7

TABLE 28 (5): EFFECT ON F5 SYSTEM OF RE-PLANNING WITH LIMITED AND UNLIMITED CAPITAL AVAILABILITY.

TABLE 28 (6)

Variable	(a) Stage I System	Optimal System	
		Lim. Cap.(e)	Cap. not Lim.(f)
Potatoes - Main Crop	45	6.1	6.1
" - Redskin		2.6	2.6
" - Earlies			
Sugar Beet		0.5	0.5
Wheat	62	61.4	61.4
Barley	140	168.5	168.5
Grass	45	57.9	57.9
Other Crops	5		
Barley Beef	200	270.7	270.7
Other Cattle		67.2	67.2
Sheep	380		
Pigs		5.6	5.6
Men	5	2.02	2.02
Potato Planters	1	0.51	0.51
Forage Harvesters			
Balers	1	0.01	0.01
Potato Harvesters	1	0.50	0.50
Combine Harvesters	1	1.00	1.00
Beet "		0.08	0.08
Potato Dressers	1	0.52	0.52
Initial Capital	27206	27334	27334
Margin	1300	3889	3889
IC/Ac.	91.6	92.0	92.0
M/Ac.	4.4	13.1	13.1
100 M/IC	4.8	14.2	14.2

TABLE 28 (6): EFFECT ON F6 SYSTEM OF RE-PLANNING WITH LIMITED AND UNLIMITED CAPITAL AVAILABILITY.

18.02 The changes in the farm margins from the present systems to the programmed optima using the same amount of capital are summarised in Table 29. These results demonstrate the effect of two of the factors

TABLE 29

FARM	PRESENT MARGIN(a)	OPTIMAL MARGIN(e)	PERCENT CHANGE
F1	11136	11756	+ 5.6
F2	9270	13168	+42.0
F3	6506	7314	+12.4
F4	13450	11946	-11.2
F5	8210	11169	+36.0
F6	1300	3889	+199.2
TOTAL	49872	59242	+18.8

TABLE 29: COMPARISON OF FARM MARGINS OBTAINED USING SAME CAPITAL SUM.

((1) and (3)) mentioned in Section 17.06 - variations in attitude to risk; variations in data (and possibly in organisational ability). The result for F4 clearly shows that these differences exist, since the farm margin derived from a fixed capital sum is £1,504 greater before re-planning than after. For example, on 140 ac. of Heavy Land this farm grew 30 acres of Maincrop potatoes, 60 acres of wheat and 50 acres of barley, while the cropping limitations for Heavy Land imposed in the planning model and based on recommendations by the majority of the farmers would allow only 28 acres of potatoes and 56 acres of wheat, and would require 56 acres of grass to precede these crops. On 275 acres of Medium Land the system intensity was a little lower than the model constraint would allow, and on 85 acres of Light Land, somewhat higher.

The changes in system when re-planning is carried out using the same capital sum vary in detail, but there are some common trends - the introduction or increase of sugar beet on five farms (from 100 acres to 240 acres on a total of 2514 acres) - a considerable reduction in potato acreage on all but one farm, where there was a slight increase (from 445 ac. to 303 ac. on a total of 2368 acres, and from 85 ac. to 92.4 ac., on 443 acres) - the reduction of grass and feed roots except on F4 and F6 - the introduction of summer fattened pigs and the tendency towards barley beef. - Because of the enterprise shifts and the resultant change in seasonal labour peaks, an increased gross output was obtained from approximately the same number of men, on four farms, and in two cases there was a large reduction in the size of the labour force.

18.03 Figures extracted from Tables 28, illustrating the effect on farm margins and tenants' capital employed of removing the constraint on capital availability, are summarised in Table 30.

The changes in farm enterprise levels from the optimal systems with capital constrained to the optimal systems with no capital constraint again vary in detail (See Tables 28 (1) - 28 (6)) but have an overall pattern. The potato acreage is increased on all farms except F6 (From 395 acres to 572 acres on a total of 2514 acres); the sugar beet acreage is further increased (From 240 acres to 405 acres on a total of 2514 acres); the cereal acreage decreased on all farms except F6: cattle (barley beef) are increased considerably on two farms, and to a lesser extent on two others; the number of men increased on all farms except F6. In general there was an increase in the intensity of the farm businesses, which utilised from 11.6 % to 88.3% more tenants capital to increase farm margins by from 9.3% to 56.6%. On F6 there is no change since a 'limited capital' program was not run for this farm, as explained in Section 18.01. The increases in farm

TABLE 30

EFFECT ON FARM MARGINS (£)			
FARM	LIMITED CAPITAL	NO CAPITAL LIMIT	PERCENT CHANGE
F1	11756	15091	+ 28.3
F2	13168	14993	+ 13.9
F3	7314	10376	+ 41.9
F4	11946	13060	+ 9.3
F5	11169	17487	+ 56.6
F6	3889	3889	0.0
TOTAL	59242	74896	+ 26.4

EFFECT ON CAPITAL EMPLOYED (£)

FARM	LIMITED CAPITAL	NO CAPITAL LIMIT	PERCENT CHANGE
F1	33027	55679	+ 68.6
F2	60293	73134	+ 21.3
F3	29532	45536	+ 54.1
F4	26364	29425	+ 11.6
F5	37544	70678	+ 88.3
F6	27334	27334	0.0
TOTAL	214094	301786	+ 41.0

'RETURN' ON MARGINAL CAPITAL

FARM	MARGIN CHANGE (£)	CAPITAL CHANGE (£)	100 M/ C
F1	3335	22652	14.72
F2	1825	12841	14.21
F3	3062	16004	19.13
F4	1114	3061	36.39
F5	6318	33134	19.07
F6	0	0	0.00
TOTAL	15654	87692	17.85

TABLE 30: CHANGES IN MARGINS AND TENANTS' CAPITAL ON REMOVAL OF CAPITAL CONSTRAINT.

margins expressed as a percentage of the capital increase (Shown in Table 30) give some indication of the average returns on marginal capital over the ranges of capital change involved - these figures are calculated after having paid 9% borrowing rate on the capital.

The figures calculated, as described in Section 12.06, as being the maximum increases which can be sustained in the problem cost row entry for Initial Capital without causing an alteration in the solution are shown in Table 31 for the two sets of solutions.

TABLE 31

FARM	LIMITED CAPITAL SYSTEMS	NO CAPITAL LIMIT SYSTEMS
F1	£18.13	£0.05
F2	£11.74	£2.78
F3	£16.94	£3.19
F4	£23.14	£1.46
F5	£17.23	£2.74
F6		£1.46

TABLE 31: MAXIMUM PERMISSABLE INCREASES IN ANNUAL COST OF £100 OF INITIAL CAPITAL, CALCULATED BY SOLUTION MATRIX ANALYSIS.

18.04 There are several points which should be noted:

(1) The acceptable rate of return on marginal capital in farming will vary with the circumstances and personality of the individual.

(2) The planning model does not include any allowance for the probability that as a farm business run by an individual increases in size and becomes more intensive, both biological and management pressures will increase to cause a progressive decrease in the

marginal efficiency of the system. These two factors could be taken as reason for the individual farmers not increasing their businesses beyond their present level, even if they are not limited by capital availability.

(3) As mentioned previously, the corporate attitude to risk and return on marginal capital may be different for a group of people than for any of the individuals comprising that group.

(4) It may be possible, by redefinition of responsibility and management specialisation, for a group of farmers to run a business which is larger and more intensive than the sum of the businesses which they as individuals could run with the same degree of marginal efficiency.

18.05 After consideration of these factors it was decided that the potential economic benefits of the amalgamation of the group of farms would be best measured by comparing the potential of the six separate farms when planned using the standard data and assumptions to obtain maximum profit given that there is no limit on the availability of capital, with the potential of the same physical resources planned as one business under the same conditions.

It was considered that the full economic advantage of amalgamation to this group of farmers should be at least as large as the result of this comparison, since the unquantifeed factors described above would tend to increase the financial benefit in practice.

19.0 The System on the Amalgamated Unit (Stage III) -(h)

19.01 As stated in Section 6.01, all the land comprising the six farms was treated as one farm for the purpose of planning its utilisation as one farm business. Thus, for further comparison (See Section 17.01) the first step, Stage III, is to compute that combination of crops and stock, and the necessary complement of men and equipment, which will give the maximum gross farm income from the resources listed in Table 4, assuming that there is no limit on the availability of capital. The second step, Stage IV, is to consider the effect of substituting for the type of equipment in present use (Listed in Table 19), such items of large, high capacity machinery as could be utilised in carrying out the crop operations required.

19.02 The same model was used to arrive at the optimal organisation for 'The Farm' as was used for planning the individual farms, with the exception that the land types were sub-divided according to the presence or absence of water for irrigating early potatoes.

Notional annual capacities for equipment, based on the approximate expected cropping pattern, were used for the first run of this program. For both potato harvesters and potato dressers, two matrix rows were used to link the numbers of machines to the work load. It was considered that since potato lifting could start with First Early varieties in mid-June and continue with second Earlies, Early Maincrop (Redskin) and Maincrop until about the end of November, it would not be sufficient to calculate the number of harvesters required from the workload during only part of the potato harvesting season. Therefore one constraint tied harvester numbers to the acreage of maincrop potatoes plus $^2/_3$ of the early maincrop acreage, while the other linked the number of harvesters to the acreage of early potatoes plus $^1/3$ of the early maincrop acreage. To define the number of potato dressers required, one constraint linked them with the tonnage of maincrop potatoes stored while the second related potato dresser numbers to the acreage of early maincrop potatoes (It was assumed that E.M.C. would be dressed as lifted, for sale off the field). Early potatoes were sold as lifted without dressing.

In order to re-define machine capacities for the second run of this problem - aimed at obtaining a solution with the numbers of machines and of men at as near integer values as possible - , a gang-work chart (See for example, Figure O, Section 20.0) was prepared on the lines suggested by Kerr (1), but with extensions for overtime work. This detailed, in terms of machines and work teams, the operations to be carried out within the appropriate seasons for the first Stage III solution. This was considered necessary when several machines of the same type would be required, because the seasonal limits for several operations were shorter than the seasonal approximations defined in Table 16, For example, although the labour requirements for sugar beet harvesting are balanced against the labour supply in the period 19th November-14th February, the sugar beet crop had to be lifted by the end of December.

A new capacity figure for each type of machine was calculated from the numbers of each machine required for the gang work chart and from the acreages etc. in the program solution. Annual machine costs were recalculated and these new coefficients were substituted in the problem data to obtain a second solution in which the numbers of men and of machines were acceptably near to integer values. The two solutions are shown in Table 32.

It will be seen that in the first solution, only 2803 acres of land were utilised. This is caused by two items - first, a rental value of £10/acre. had been set on all land and this, plus £4/acre for sundry overhead costs, meant

TABLE 32

Variable	STAGE III SOLUTIONS	
	First Solution	Second Solution
Potatoes-Maincrop	114.95 acres	114.95 acres
" -Redskin	373.25 acres	373.25 acres
" -Early	199.00 acres	199.00 acres
Sugar Beet	191.66 acres	191.66 acres
Wheat	821.29 "	829.28 "
Barley	955.15 "	947.17 "
Grass	147.70 "	155.69 "
TOTAL ACRES	2803 "	2811 "
Men	35.02	32.69
Potato Planters	4.91	3.00
Forage Harvesters	–	–
Balers	1.23	0.97
Potato Harvesters	7.00	7.00
Combines	7.11	3.00
Beet Harvesters	1.86	5.00
Potato Dressers	3.89	4.00
Hay (Ac.Equiv.)	122.67	137.95
Grazing (")	14.41	5.79
Barley Beef (Slats)	1659.11	1755.99
Winter Fed Cattle	271.84	182.54
18mth.Friesians	259.04	258.76
Pigs Fattened	1838.9	1658.9
Straw Used (Tons)	543.8	471.6
Beet Tops Fed (Tons)	1157.3	583.9
F.Y.M. (Tons)	10122.0	10225.0
Initial Capital (£)	246957	238540
Farm Margin	84523	86047

TABLE 32:(h) STAGE III (AMALGAMATED UNIT) SOLUTIONS:- NON-INTEGER AND NEAR-INTEGER VALUES FOR MEN AND MACHINES.

that there was in the matrix a cost of £14 per acre for the use of land. Second, rotational limitations were expressed in data as constraint constants rather than as ratios of the land used. Thus, on 40 acres of Light Land on the F1 (irrigable) section of the Farm, there was a choice of three crops, Wheat, Barley, or Grass (See Table 5). Wheat + Barley were limited to 32 acres, with Wheat ≤ Grass. The cost of £14/acre made it uneconomic to carry stock to consume 8 acres of grass even although this would have allowed 8 acres of wheat to be grown at a greater gross margin than the 8 acres of barley it would replace. The form of the rotational constraints allowed 32 acres of barley only to be grown, leaving 8 acres unused, incurring no rental charge. While this is economically sound, it is impracticable and therefore for the second run the cost row entry for the 'Land Use' variable was removed, although the working capital coefficients were unaltered. The cost of 2811 acres at £14/acre was deducted from the functional value in the resulting solution, to obtain the Farm margin.

19.03 In Table 33 the organisation of and financial results from the amalgamated unit using normal types of equipment (STAGE III, Second solution), are compared with the total of crops and stock etc. in the optimal systems of the six individual farms when planned with no limit on capital availability (STAGE II - Third column, Tables 26).

The financial effect of the amalgamation is summarised in the form of a Gross Margin account in Table 34. It should be noted that while Table 34 Stage II includes for example, 466.45 acres of Early Maincrop Potatoes at a Gross Margin of £98.7/acre, and Stage III has 373.25 acres at £96.3/acre, these are the averages for the 466.45 acres and 373.25 acres, which comprise various acreages on a range of soils, each of which has a different gross margin

TABLE 33

VARIABLE	STAGE II TOTAL	STAGE III
Potatoes-Maincrop	34.12	114.95
" -Redskin	466.45	373.25
" -Early	71.51	199.00
Sugar Beet	405.93	191.66
Wheat	786.34	829.28
Barley	891.51	947.17
Grass	155.14	155.69
Men	39.75	32.69
Potato Planters	5.62	3.00
Forage Harvesters	–	–
Balers	3.12	0.97
Potato Harvesters	10.42	7.00
Combines	7.56	3.00
Beet Harvesters	9.79	5.00
Potato Dressers	6.56	4.00
Hay (Ac.Equiv.)	38.03	137.95
Grazing (")	103.92	5.79
Barley Beef	2368.60	1755.99
Winter Fed Cattle	235.22	182.54
Grass Fed Cattle	130.29	
18 mth. Friesians	6.82	258.76
Sheep	131.0	
Pigs Fattened	504.4	1658.9
Straw Used (Tons)	127.5	471.6
Beet Tops Fed (Tons)	240.0	583.9
F.Y.M. (Tons)	11014	10225
Initial Capital (£)	301786	238540
Farm Margin	74891	86047
Initial Capital/acre	107.3	84.8
Margin/acre	26.6	30.6
100M/IC	24.8	36.1

TABLE 33: COMPARISON OF SUM OF INDIVIDUAL FARM OPTIMAL SYSTEMS (STAGE II) AND AMALGAMATED UNIT SYSTEM WITH STANDARD EQUIPMENT (STAGE III).

(See Appendix C). (That the farm margins and capital sums shown in Table 34 and Table 35 do not exactly match those in Table 33, is due to rounding errors).

Although there is a considerable change in the overall cropping pattern from Stage II to Stage III, with a 20% increase in potatoes incorporating a shift from early maincrop to early and maincrop varieties, and a 53% reduction in sugar beet, there is very little change in the total gross margin from the almost identical cash crop acreage. Forage-fed livestock make a greatly increased contribution to the total gross margin, but in doing so, use 46.5% of the available court space, compared with 14.1% at Stage II. This reduced the space available for other purposes so that the gross margin from Barley Beef dropped, and 'miscellaneous' income (derived from buying barley in Autumn at £20/ton and selling it in spring at £22/ton) disappeared. The result is that Gross Margin from sources other than cash crops is in total very little altered and thus the total gross margin from 2811 acres and the buildings thereon, is fractionally decreased.

The re-organisation of crops and stock is in fact a rationalisation which has led to a reduction in total staff from 39.75 men to 32.69 men although the total labour cost is only reduced by 2% due to an increase in overtime from 41% to 84% of the maximum overtime allowed per man of 720.25 hours/year (which is 50% of the total available overtime), and an increase in casual labour cost for potato dressing from £432 to £1987. Power costs and interest charges are however reduced by £5036 and £5804 respectively, a total of £10,840, so that these account for almost the whole of the £11,141 improvement in Farm Margin (in Table 34) Since the reduction in interest charge arises from the £63,246 (20.9%) reduction in Initial Capital, the composition of the initial capital required for Stage II and for Stage III is analysed in <u>Table 35</u> This shows that there has been a reduction of the capital required in each

TABLE 34

ENTERPRISE	STAGE II TOTAL			STAGE III		
	QUANTITY	GM/UNIT	TOTAL	QUANTITY	GM/UNIT	TOTAL
Pot.-MC	34.12	94.2	3215	114.94	86.4	9935
Pot.-E.M.C.	466.45	98.7	46055	373.25	96.3	35942
Pot.-Early	71.51	98.0	7007	199.00	98.2	19537
S. Beet	405.93	64.6	26241	191.66	68.7	13163
Wheat	786.34		36164	829.28		37944
Barley	891.51		30416	947.17		32749
Crop Totl.	2655.86	56.1	149098	2655.30	56.2	149270
W. Catt.	235.22		5058	182.54		3925
S. "	130.29		2020			
Fries.	6.82		358	258.76		13585
Sheep	131.00		904			
			8340			17510
Forage	155.14		1845	155.70		1718
For. Tot.		41.9	6495		101.4	15792
B.Beef	2368.6		40289	1755.99		29868
Pigs	504.4		893	1658.9		2938
Misc.			1779			
Total			42961			32806
Farm G.M.		70.6	198554		70.4	197868
Labour			34593			33868
Power			24288			19252
Rent			28110			28110
O. Heads			11244			11244
Interest			22098			16294
Misc.			3294			3032
Tot. F.C.		44.0	123627		39.8	111800
Fm. Marg.		26.6	74927		30.6	86068

TABLE 34: GROSS MARGIN ACCOUNT COMPARISON OF STAGE II (TOTAL) AND STAGE III.

TABLE 35

		STAGE II TOTAL		STAGE III	
VARIABLE	VAL. CAP./UNIT	UNITS	TOTAL	UNITS	TOTAL
Tractor	1195	39.75	47501	32.69	39065
Pot. Planter	405	5.62	2276	3.00	1215
Forage Harv.	376				
Baler	758	3.12	2365	0.97	736
Pot. Harv.	860	10.42	8961	7.00	6020
Combine	2040	7.56	15422	3.00	6120
Beet Harv.	470	9.79	4601	5.00	2350
Pot. Dresser	850	6.56	5576	4.00	3400
Machinery			86702		58906
Barley Beef	63	2368.6	149222	1756	110628
Wint. Cattle	94	117.61	11055	91.27	8579
Ewes	12	131	1572		
Friesians	103.14	6.82	703	258.76	26689
Stock			162552		145896
Potatoes	17	74.94	1274		
Wheat	27	1047.73	28289	1100.1	29703
Barley	22	660.4	14529		
Crop	4.87	786.34	3829	829.28	4039
Tot. Crop			47921		33742
Working Cap.			4578		
Initial Cap.			301753		238544

TABLE 35: ANALYSIS OF INITIAL CAPITAL COMPOSITION FOR STAGE II AND STAGE III.

of the three sections 'Machinery' 'Stock' and 'Crop' and that Stage III does not require working capital to cover the deficit of expenditure over income in the March/April period, as does Stage II. Capital in equipment is reduced by £27,796 (32%); Capital in stock is reduced by £16,656 (11%); Capital in crops in store and planted is reduced by £14,179 (30%). Therefore, adding £2502 (Machinery capital reduction of £27,796 @ 9%) of the reduction in interest charges shown in Table 34, to the £5036 reduction in Power costs (Depreciation, repairs and tractor fuel) gives a saving of £7536 because of the reduction in the numbers of machines required. This accounts for 67.7% of the farm margin increase from Stage II to Stage III.

19.04 Since the changes in the machinery complement and in power costs have apparently a major effect on profitability, the composition of the power costs at Stage II and Stage III is shown in Table 36. Although there is a considerable increase required in machine capacity at harvest time (combines and potato harvesters), the Season IV (16th August-18th November) work pattern arising from the Stage III solution, which is illustrated in Figure O, indicates that it should be possible to complete barley harvesting by about 20th September, and wheat harvesting by 17th October, while lifting early maincrop potatoes is completed, and maincrop lifting started, on 8th October. Table 37 details the data used to construct the Period IV Section of Figure O; the same data, in the form of man hours, was used in the programming model. For convenience the number of men has been rounded to 33 in constructing Figure O, so that there are 447 fewer overtime man hours in the overtime section of the figure than there are in the program solution.

TABLE 36

MACHINE	NUMBER	AVERAGE CAPACITY	AV. ANNUAL DEPRECIATION	AV. ANNUAL REPAIRS & FUEL	TOTAL ANNUAL COST
			STAGE II		
Tractor	39.75		168.0	229.37	15796
Pot. Planter	5.62	101.8	34.9	17.3	293
Baler	3.12	77.4(T)	48.7	4.9	168
Potato Harv.	10.42	54.9	188.3	137.8	3398
Combine	7.56	221.9	185.0	82.1	2019
Beet Harv.	9.79	41.5	55.1	23.8	773
Pot. Dresser	6.56	76.3	119.3	47.9	1098
F.Y.M.					743
					24288

MACHINE	NUMBER	AVERAGE CAPACITY	AV. ANNUAL DEPRECIATION	AV. ANNUAL REPAIRS & FUEL	TOTAL ANNUAL COST
			STAGE III		
Tractor	32.69		168.0	229.37	12990
Pot. Planter	3.00	229.1	48.0	38.6	260
Baler	0.97	912.8 (T)	79.4	41.3	117
Potato Harv.	7.00	98.2	240.0	180.0	2940
Combine	3.00	592.2	244.3	140.7	1155
Beet Harv.	5.00	38.3	54.0	22.3	382
Pot. Dresser	4.00	122.1	129.0	55.0	736
F.Y.M.					672
					19252

TABLE 36: COMPOSITION OF TOTAL POWER COSTS AT STAGE II AND AT STAGE III.

TABLE 37

JOB	GANG	GANG HRS./UNIT	UNITS	TOT. GANG HRS.
Lift $^2/_3$ E.M.C. (M-H)	4	6.25	222.15	1388.4
" " " (M)	4	5.555	26.67	148.1
Dress $^2/_3$ E.M.C.	6	6.0975	248.82	1517.4
Lift M.C.	4	6.25	114.95	718.4
Combine/Dry Barley	3	0.7125	947.17	674.8
" " "Wheat	3	0.7375	829.28	611.6
Bale Straw	2	3.125	47.16	147.4
Stack Straw	3	3.125	47.16	147.4
Plough $\frac{1}{4}$ MC + Bar(H)	1	2.86	68.78	196.7
Plough $\frac{1}{2}$ Wheat (M)	1	2.222	143.33	318.5
" Wheat (H, M-H, T)	1	2.5	511.94	1279.9
Sow $\frac{1}{2}$ Wheat (M)	2	0.383	143.33	54.9
" Wheat (H, M-H, T)	2	0.49	511.94	250.9
Barley Beef	1	0.76	1756.0	1334.6
Pigs	1	0.24	1658.9	398.1
Friesians	1	2.14	258.76	553.7

TOTAL W.D. MAN HOURS = 18308.9

= 33 Men @ 438.2 Hours W.D.N.T./Man + 116.6 Hours W.D.O.T./Man.

TABLE 37: STANDARD MAN HOUR LABOUR COEFFICIENTS CONVERTED TO GANG HOURS FOR CONSTRUCTION OF PERIOD IV, FIGURE O.

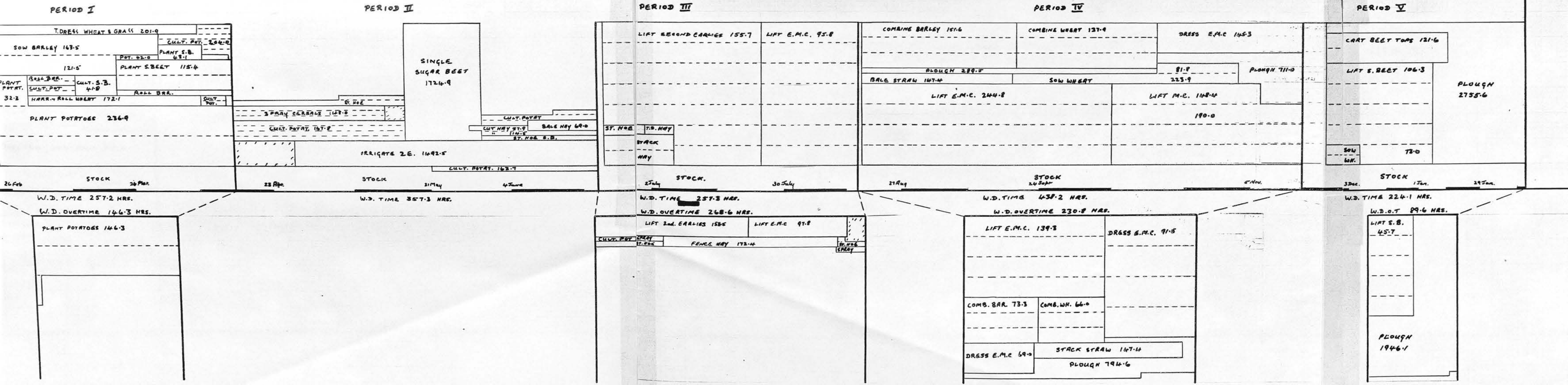
20.0 The Effect of Introducing Large Machinery - (i)

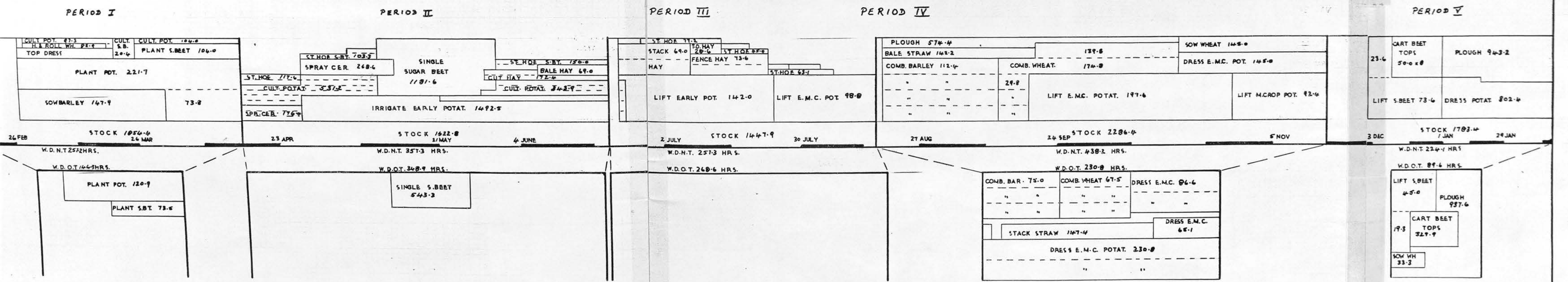
20.01 The results shown in Table 35 and Table 36 indicate that the general effect of amalgamating the six farms would include a re-distribution of the feasible crops and stock which, although not increasing the total Gross Margin from 2811 acres, would allow a considerable reduction in the numbers of machines required, thus increasing the farm margin by reducing running costs, depreciation, and interest charges. The number of men employed was reduced by 17½%, but the cost of wages fell by only 2% because of increased overtime and casual labour.

20.02 The Labour/Machinery complex was therefore examined further since it seemed probable that it would be economic on a farm of this size, to utilise much larger equipment than could be justified on any of the individual farms.

This was done by drafting a gang-work chart (Figure P) in which various high output machines and systems replace the standard equipment, in carrying out the workload defined at Stage III.

Three main changes were assumed, concerning potato harvesting, sugar beet harvesting and tractors. Because of the projected increase in tractor horse-power, several changes in cultivation rates were also possible. The original labour force for Stage III was 32.69 men (adjusted to 33 men in Figure O). With alterations to the equipment used, Figure P demonstrates the possibility of doing the same work with a staff of 21 men.


PERIOD I
PERIOD II
PERIOD III
PERIOD IV
PERIOD V
T. DRESS WHEAT & GRASS 201.9
CULT. POT. 204.0
SOW BARLEY 163.5
PLANT S.B. 48.1
POT. 42.0
121.5
PLANT S.BEET 115.4
PLANT POTAT. 32.3
ROLL BAR.
CULT. POT
CULT. S.B. 41.8
ROLL BAR.
HARR.+ROLL WHEAT 172.1
CULT. POT.
PLANT POTATOES 236.9
SINGLE SUGAR BEET 1724.9
ST. HOE
SPRAY CEREALS 148.0
CULT. POTAT. 167.8
CULT. POTAT
CUT HAY 57.9
" 114.5
BALE HAY 69.0
ST. HOE S.B.
IRRIGATE 2E. 1492.5
CULT. POTAT. 162.7
ST. HOE
T.D. HAY
STACK
HAY
LIFT SECOND EARLIES 155.7
LIFT E.M.C. 95.8
COMBINE BARLEY 151.6
COMBINE WHEAT 137.9
DRESS E.M.C 145.3
PLOUGH 289.5
81.8
PLOUGH 711.0
BALE STRAW 147.4
SOW WHEAT
223.9
LIFT E.M.C. 244.8
LIFT M.C. 148.4
190.0
CART BEET TOPS 121.6
LIFT S. BEET 106.3
PLOUGH 2755.6
SOW WH.
78.0
26 Feb
STOCK
26 Mar.
23 Apr.
STOCK
21 May
4 June
2 July
STOCK.
30 July
27 Aug
STOCK
24 Sept
5 Nov.
3 Dec.
STOCK
1 Jan.
29 Jan.
W.D. TIME 257.2 HRS.
W.D. OVERTIME 146.3 HRS.
W.D. TIME 357.3 HRS.
W.D. TIME 257.3 HRS.
W.D. OVERTIME 268.6 HRS.
W.D. TIME 438.2 HRS.
W.D. OVERTIME 230.8 HRS.
W.D. TIME 224.1 HRS.
W.D.O.T 89.6 HRS.
PLANT POTATOES 146.3
LIFT 2nd. EARLIES 158.5
LIFT E.M.C 97.8
CULT. POT
SPRAY
ST. HOE
FENCE HAY 172.4
ST. HOE
SPRAY
LIFT E.M.C. 139.3
DRESS E.M.C. 91.5
COMB. BAR. 73.3
COMB. WH. 66.0
DRESS E.M.C 69.0
STACK STRAW 147.4
PLOUGH 794.6
LIFT S.B. 45.7
PLOUGH 1946.1



PERIOD I
PERIOD II
PERIOD III
PERIOD IV
PERIOD V
CULT. POT. 67.3
H. & ROLL WH.
CULT. S.B. 20.4
CULT. POT. 104.0
PLANT S.BEET 104.0
TOP DRESS
PLANT POT. 221.7
SOW BARLEY 147.9
73.8
STOCK 1854.4
26 FEB
26 MAR
W.D.N.T. 2572 HRS.
W.D.O.T. 1443 HRS.
PLANT POT. 120.9
PLANT S.BT. 73.5
ST. HOE S.BT. 703.5
SPRAY CER. 268.4
SINGLE SUGAR BEET 1181.6
ST. HOE
CULT. POTAT.
SPR. CER.
IRRIGATE EARLY POTAT. 1492.5
ST. HOE S.BT. 150.0
BALE HAY 69.0
CUT HAY
CULT. POTAT. 342.9
STOCK 1622.8
23 APR
1/MAY
4 JUNE
W.D.N.T. 357.3 HRS.
W.D.O.T. 348.9 HRS.
SINGLE S.BEET 543.3
ST. HOE
STACK 69.0
T.D. HAY 28.6
ST. HOE
FENCE HAY 73.6
HAY
ST. HOE 63.1
LIFT EARLY POT. 142.0
LIFT E.M.C. POT. 98.8
STOCK 1447.9
2 JULY
30 JULY
W.D.N.T. 257.3 HRS.
W.D.O.T. 268.6 HRS.
PLOUGH 574.4
BALE STRAW 142.2
139.8
SOW WHEAT 145.0
DRESS E.M.C. POT. 145.0
COMB. BARLEY 112.4
COMB. WHEAT. 174.8
29.8
LIFT E.M.C. POTAT. 197.6
LIFT M.CROP POT. 92.4
STOCK 2286.4
27 AUG
24 SEP
5 NOV
W.D.N.T. 438.2 HRS.
W.D.O.T. 230.8 HRS.
COMB. BAR. 75.0
COMB. WHEAT 67.5
DRESS E.M.C. 86.6
DRESS E.M.C. 65.1
STACK STRAW 147.4
DRESS E.M.C. POTAT. 230.8
CART BEET TOPS 50.0 x 8
23.6
PLOUGH 943.2
LIFT S.BEET 73.6
DRESS POTAT. 802.4
STOCK 1783.4
3 DEC
1 JAN
29 JAN
W.D.N.T. 224.1 HRS.
W.D.O.T. 89.6 HRS.
LIFT S.BEET 45.0
PLOUGH 937.6
CART BEET TOPS 329.9
19.3
SOW WH 33.3

20.03 Potato Harvesting: The present system uses a potato harvester employing four men (1 towing, 1 on harvester, 2 carting), plus 5 casual workers on the harvester. The rate of work is 1.6 ac./day on Heavy, Medium-Heavy and Thin land, and 1.8 ac./day on Medium and Light land, which, with the 25% time-waste allowance give 6.25 hrs./ac. and 5.555 hrs./ac. respectively, with a team of 4 men. Thus in Period III (21st June to 14th August) lifting 199.0 acres of second early potatoes on Medium and Light land takes 1105.4 hours, and lifting one third of the early maincrop acreage (111.1 acres on Medium-Heavy land and 13.33 acres on Medium land) takes 768.4 hours – a total of 7495.2 farm staff man hours.

The system included in Figure P is used in Norfolk and Lincolnshire (2), and requires two side-delivery two-row elevator diggers followed by a two-row rear delivery elevator digger to lift six drills of potatoes into one row. On heavier soils another rear delivery digger is used ahead of the side delivery diggers and all six drills then get a second run through with the second rear delivery digger. The potatoes are then lifted and loaded using a J-202 two-row harvester, and carted with high capacity self emptying trailers. The rates of work quoted for this system are: 2 acres/hour @ 18 Tons/acre (Ruston, Norfolk); 10 acres/day with insufficient trailers or 15-18 acres/day with adequate trailers (Holbeach, Lincs.)

The basic rate of work on Medium and Light land for Figure P was taken to be 14 acres/day @ 12 Tons/acre of E.M.C. potatoes, using two rear delivery diggers. Fourteen acres/8 hours = 0.57143 hr./acre, to which the 25% time-waste allowance is added to give the squad time per acre of 0.7142 hours. The rate of work on Heavy, Medium-Heavy, and Thin land was assumed to be in the same proportion to that on Medium and Light land as at present. i.e. 14 ac. x 1.6/ 1.8 = 12.44 ac./day, requiring 0.8038 squad hours/acre. Trailer numbers were calculated assuming a 12 Ton crop lifted at 14 acres/day, $\frac{3}{4}$ hour average turnround time, and 4 ton loads. Four trailers would be required, and an electronic separator was substituted for the grader-elevator used in the cases reported. Thus the equipment and staff required are:

Two rear-delivery elevator diggers	£680	2 men
Two side-delivery elevator diggers	£1220	2 men
One J-202 two row harvester	£1750	1 man
Four self emptying trailers	£2600	4 men
Electronic separator	£2000	
	£8250	9 men

The time taken to lift 199.0 acres of early potatoes and 124.43 acres of early maincrop potatoes by this system is (199.0 + 13.33) x 0.7142 + (111.1 x 0.8038) = 240.9 hours x 9 men = 2168.1 farm staff man hours. It is assumed that five casual workers would be required on the potato harvester, thus involving 240.9 x 5 = 1204.5 hours of casual labour

20.04 Sugar Beet Harvesting The present work rate is based on lifting three acres per $7\frac{1}{2}$ hour day on Medium-Heavy and Light land with a 12 Ton crop, using four men. This gives 2.5 hours per acre + 25% = 3.125 hours x 4 men = 12.5 man hours/acre. On Medium land, the labour requirement was increased by 25% because of heavier yields (= 15.625 man hours/acre) Thus to lift 163.33 acres of beet on Medium land and 28.33 acres on Light land took 726.5 hours, or 2906.0 man hours.

The method used in Figure P is again a multi-stage system, which has been used in France since 1962 and was demonstrated in Lincolnshire in 1967 (3). Six rows are handled at once - the beet is first topped, a second machine lifts and windrows the six rows into one row and partially cleans them, and the final implement is a pick-up cleaner-loader. This system is claimed to lift 2-2½ acres per hour, and has been demonstrated lifting 44 acres at 18 Tons/acre in 3 days.

The basic rate of work on Heavy-Medium and Light land was taken to be 1.8 acres/hour with a 12 Ton crop, giving (with the 25% time-waste allowance) 0.6944 hours/acre. On Medium land this was increased by 25% to give 0.868 hours/acre.

The equipment and staff required are:

One Topper	£1410	1 man
One lifter-windrower	£885	1 man
One cleaner-loader	£1470	1 man
Carting		4 men
Dump		1 man
	£3765	8 men

The number of men required for carting is based on lifting 1.8 acres/hour at 14 Tons/acre, 30 min. average turn round time, and 3 Ton loads. The time taken to lift 191.66 acres of beet by this system is (163.33 x 0.868) + (28.33 x 0.6944) = 161.5 hours x 8 men = 1292.0 man hours.

20.05 Tractors In computing Stage III the tractor type assumed was a MF-165 costing £1035 and ploughing with a 2 x 14" furrow plough. Since heavy equipment is involved in the potato and beet harvesting systems described in Sections 20.03 and 20.04, and the number of men available for ploughing would be reduced, a John Deere 40/20 type was substituted. It was assumed that this would be capable of pulling a 5 x 14" furrow plough, so that the time per acre of land ploughed is reduced to 2/5 ths. of the original times.

Thus, ploughing in Period V (19th Nov. - 14th Feb.) which takes 4701.7 man hours at Stage III, as detailed below, is reduced to 1880.8 man hours in Figure P.

PERIOD V PLOUGHING - STAGE III

Plough $\frac{3}{4}$ of M.C. Pot. + barley	- H. land	: 206.34 ac. @ 2.86 hr/ac.		= 590.1 mh.
Plough E.M.C. Pot. + barley	- M-H land	: 999.75 ac. @ 2.5	"	= 2499.4 mh.
Plough E.M.C., 2nd early pot., S.Beet + $\frac{1}{2}$ Wheat	- M. land	: 511.66 ac. @ 2.222	"	= 1136.9 mh.
2nd early pot., S.beet, Wheat + barley	- L. land	: 117.00 ac. @ 2.0	"	= 234.0 mh.
Plough M.C. Pot. + barley	- T. land	: 96.5 ac. @ 2.5	"	= 241.3 mh.
				4701.4 mh.

20.06 Following on the availability of heavy duty tractors, several other changes in work rates were assumed, mainly based on doubling the width of implement used. For two team jobs, planting potatoes and sowing barley, the method of work was also altered. The changes made, other than potato harvesting, and ploughing, and beet harvesting, are detailed below.

POTATO PLANTING — STAGE III

Rotavate (5')	@ 5.6 ac/dy. = 1.43 h/ac.	- 1 man = 1.43 mh.	)	= 5.626 mh/ac. + 25% = 7.032 mhr/ac.
Harrow	@ 48 " = 0.166 "	- 1 man = 0.856 mh.	)	
K3 twice	@ 23 " = 0.345 "		)	
Plant (4 row)	@ 9.6 " = 0.835 "	- 4 men = 3.34 mh.	)	= 1.172 hr. x 6 men.

STAGE IV

Rotavate ½ (8') @ 9 ac/dy. = 0.89 h/ac. - 1 man = 0.445 mh.)
" @ 9 " = 0.89 " - 1 man = ") = 2.909 mh/ac. + 25%
Harrow (W x 2) @ 100 " = 0.08 ")) = 3.636 mhr/ac.
) - 1 man = 0.42 mh.)
K3 twice(") @ 47 " = 0.17 ")) = 0.606 hr. x 6 men
Plant (6 row) @ 15 " = 5.33 " - 3 men = 1.599 mh.)

BARLEY SOWING & ROLLING STAGE III

K3 @ 23 ac/dy. = 0.345 h/ac. - 1 man = 0.345 mh.) = 0.963 mh/ac. + 25%
Drill @ 27 " = 0.286 " - 1 man = 0.286 mh.) = 1.204 mhr/ac.
Fert. @ 48 " = 0.166 " - 2 men = 0.332 mh.) = 0.301 hr. x 4 men
Roll @ 40 " = 0.200 h/ac. - 1 man = 0.200 mh. + 25% = 0.25 hr x 1 man

STAGE IV

K3 (W x 2) @ 47 ac/dy. = 0.17 h/ac. - 1 man = 0.17 mh.)
Drill (") @ 50 " = 0.16 " - 2 men = 0.32 mh.) = 0.75 mh/ac. + 25%
Fert. (") @ 100 " = 0.08 " - 2 men = 0.16 mh.) = 0.9375 mhr/ac.
Roll (") @ 80 " = 0.10 " - 1 man = 0.10 mh.) = 0.1562 hr x 6 men

TOP DRESSING Stage III - 48 ac/day = 0.2075 hr. x 2 men = 0.4150 mh/ac.
Stage IV - 100 ac/day = 0.1 hr. x 2 men = 0.2 mh/ac.

HARROW & ROLL WHEAT

Stage III - 48 ac/day = 0.2075 hr. x 2 men = 0.4150 mh/ac.
Stage IV - 100 ac/day = 0.1 hr. x 1 man = 0.1 mh/ac.
(Implements doubled in width and pulled in tandem).

SUGAR BEET SOWING STAGE III

Harrow @ 48 ac/dy = 0.166 h/ac. - 1 man = 0.166 mh.) = 0.698 mh/ac + 25%
Roll @ 40 " = 0.200 " - 1 man = 0.2 mh.) = 0.8725 mhr/ac.
Fert. @ 48 " = 0.166 " - 2 men = 0.332 mh.) = 0.218125 hr. x 4 men

SUGAR BEET SOWING (Cont.)

Rotavate (5')	@ 5.6 ac/dy	= 1.43 h/ac	- 1 man	= 1.43 mh	)= 3.43 mh/ac + 25%
Sow (5 row)	@ 8.0 "	= 1.00 "	- 2 men	= 2.00 mh	)= 4.2875 mhr/ac. = 1.4292 hrs x 3 men

STAGE IV

Harrow (Wx2)	@ 100 ac/dy	= 0.08 h/ac	- 1 man	= 0.08 mh	)= 0.34 mh/ac + 25%
Roll (")	@ 80 "	= 0.10 "	- 1 man	= 0.10 mh.	)= 0.425 mhr/ac
Fert. (")	@ 100 "	= 0.08 "	- 2 men	= 0.16 mh	)= 0.1062 hrs x 4 men
Rotavate (8')	@ 9 "	= 0.89 "	- 1 man	= 0.89 mh	)= 2.223 mh/ac + 25%
Sow (7 row)	@ 12 "	= 0.667 "	- 2 men	= 1.333 mh	)= 2.779 mhr/ac. = 0.926 hrs. x 3 men

Potato inter-row cultivations It is assumed that early season (Period I) cultivations can be done at double the acreage per day, but that those later in the year are carried out at the present rate because of greater vulnerability of the crop to physical damage.

Wheat Sowing Width of harrows and drill doubled, so hours per acre are halved from 0.49 hrs./ac. on Heavy, Medium-Heavy and Thin land, and 0.383 hrs./ac. on Medium and Light land, to 0.245 hrs./ac. and 0.1915 hrs./ac., but three men are employed instead of two.

Potato Dressing: - Early Maincrop: This is intended as wet-weather work for a team of 6 farm staff plus two casual workers, with the option of using dry weather (W.D. time) if it is available. For Stage III the basic rate of dressing is 18 Tons/day = 1.64 acres @ 11 Tons/acre., taking 6.0975 hours/acre (including 25% time wastage). Employing six farm staff uses 9103.2 man hours plus 3034.4 hours of casual labour to dress $\frac{2}{3}$ of the early maincrop acreage (248.82 acres) in Period IV (16th Aug. - 18th Nov.).

It was assumed that the rate of work could be slightly increased to a basic 18.526 tons (1.6842 acres) per day so that 5.9375 hours are required per acre. Eight men are still used but only four are farm staff, so that to dress 248.82 acres, 5909.6 man hours plus 5909.6 hours of casual labour are required. Of the 9103.2 man hours at Stage III and 5909.6 man hours at Stage IV, 5538.6 man hours and 2529.5 man hours are available in wet weather, the remainder of the work being done in W.D. time. The increase in casual labour cost is 5909.6 - 3034.4 = 2875 hrs. @ £0.325 = £934.4.

Maincrop: In the planning model, casual labour was made available in Period V (19th Nov. - 14th Feb.) to supplement farm staff in dressing stored potatoes. In the Stage III solution all potato dressing was done by casual labour, and some casual labour was used for other wet weather work (e.g. carting F.Y.M. and boxing early potato seed). In Stage IV the same change in rate of potato dressing is assumed as for Early Maincrop potatoes, 801.7 man hours are available in W.D. time for wet weather work, and an additional 2244.2 hours of casual labour are required at a cost of £729.4.

20.07 The cost of 32.69 men with standard equipment at Stage III is detailed in Table 38 and the comparative cost of carrying out the same work with 21 men and the equipment discussed above, is shown in Table 39.

A comparison of these two tables shows that with the change in equipment the farm staff can be cut from 32.69 men to 21 men at a saving of £8767.5 (-35.7%). Overtime increases from 606 hours/man/year to 645 hours/man/year but the total cost of overtime work falls by £3171.4 (-43.2%). The cost of casual labour for lifting potatoes decreased from £4826.1 to £694.9 due to the large reduction in man hours/acre and a decrease in the proportion of casual workers to farm staff. On potato dressing, the proportion of casual workers increases and the cost of casual labour increases by £2131.6 (+ 61.0%). The total cost

TABLE 38

ITEM	UNITS	ANN. COST - £/UNIT	TOT. COST - £/YEAR	VALN. CAP.
Men	32.69	750.0	24517.5	
W.D.O.T.-P.1	1876.5	.3708	695.8	
" -P.3	1624.9	"	602.5	
" -P.4	7544.6	"	2797.5	
" -P.5	2928.5	"	1085.9	
Wet O.T.-P.3	2908.6	.3707	1078.2	
" P.4	2915.9	"	1080.9	
Casual -P.5	6197.6	.325	2014.2	
Cas.- Lift M.C.	2873.8	"	934.0	
" - " E.M.C.	9331.3	"	3032.7	
" - " 2.E.	2644.2	"	859.4	
" - Dr.E.M.C.	4549.9	"	1478.7	
			40177.3	
Tractors	32.69	397.37	12990.0	39065
Pot. Planter	3.00	86.60	259.8	1215
Balers	0.97	120.70	117.1	736
Pot. Harv.	7.00	420.00	2940.0	6020
Combine	3.00	385.00	1155.0	6120
Beet Harv.	5.00	76.30	381.5	2350
Pot. Dresser	4.00	184.00	736.0	3400
F.Y.M.			671.8	
			19251.2	£58906
Valn. Cap.	589.06	9.00	5301.5	
			£64730.0	

TABLE 38: COST OF LABOUR, POWER AND INTEREST ON EQUIPMENT VALUATION CAPITAL AT STAGE III (AMALGAMATED UNIT - STANDARD MACHINES).

TABLE 39

ITEM	UNITS	ANN. COST - £/UNIT	TOT. COST - £/YEAR	VALN. CAP.
Men	21.0	750.0	15750.0	
W.D.O.T.-P.1	1118.3	.3078	344.2	
" -P.2	503.3	"	154.9	
" -P.4	4846.8	"	1491.8	
" -P.5	1881.6	"	579.2	
Wet-O.T.-P.1	1268.4	.3077	390.3	
" -P.3	2055.9	"	632.6	
" -P.4	1873.2	"	576.4	
Casual P.5	8441.6	.325	2743.5	
Cas.-Lift M.C.	369.6	"	120.1	
" - " E.M.C.	1200.1	"	390.0	
" - " 2.E.	568.5	"	184.8	
" - Dr.E.M.C.	8864.7	"	2881.0	
			26238.8	
Tractors(40/20)	16.0	1046.90	16750.4	48000
" (MF 165)	5.0	397.37	1986.9	5975
Pot.Planters	1.0	243.20	243.2	608
Balers	1.0	120.70	120.7	736
Pot.Hv.(Syst.)	1.0	5810.70	5810.7	8250
Combines	4.0	335.00	1340.0	8160
Bt.Hv.(Syst.)	2.0	589.20	1178.4	7530
Pot. Dress	4.0	184.00	736.0	3400
F.Y.M.			671.8	
			28838.1	£82659
Val. Cap.	826.59	9.00	7439.3	
			£62516.2	

TABLE 39: COST OF LABOUR, POWER AND INTEREST ON EQUIPMENT VALUATION CAPITAL AT STAGE IV (AMALGAMATED UNIT - LARGE MACHINES).

of labour falls by £13938.5 (- 34.7%).

The total annual cost of machinery (repairs, fuel and depreciation) increases by £9586.9 (+ 49.8%), the major changes being in tractor power (+ £5747.3 = 44.2%); potato harvesting (+ £2870.7 = 97.6%); and beet harvesting (+ £796.9 = 208.8%). The substitution of machinery for man power also increases the valuation capital required by £23753, so incurring an additional £2137.8 in interest charges.

Thus the net effect of making the particular equipment changes which have been discussed, in order to carry out the work required for an unchanged cropping and stock system, is to reduce the total cost of the labour/machinery complex by £2213.8 and so to increase the farm margin calculated at Stage III (see Table 33) by this amount, from £86047 to £88261. There are, without doubt, less costly labour/machinery systems for servicing the cropping pattern calculated for Stage III, but with the very large range of equipment and methods available, to discover the minimal cost combination would involve a great deal of work and would require a more flexible technique for selecting the minimal cost labour/machinery complex than could be found in the course of this study. For example, the method suggested by MacHardy (4) using Lagrange Multipliers appears to be satisfactory only when a whole operation is carried out by one team of men (i.e. one combine carrying out all harvesting work), and it is therefore unsuitable for application to very large farm systems where there may be several teams working in parallel.

The potential farm margin from the 2811 acre unit is therefore taken to be £88261, from a tenants' capital investment of £262293.

21.0 Business Structure and the Effects of Taxation

21.01 There are three points which should be noted in relation to the material contained in Section 21.0

(1) The subject of tax accountancy is large and complex. Therefore if the group of farmers who co-operated in this study were in fact to amalgamate their businesses, it would be essential to employ a tax specialist in order to minimise the current and future tax load on earnings, and to deal with the intricacies of estate duty and inheritance. The only purpose of the much simplified calculations which follow, is to obtain some indication of the effect that the current taxation system might have on the gross income advantage produced by amalgamation.

(2) Methods of taxation and rates of taxation are subject to annual review and possible alteration by the Government, and therefore a course of action which is relatively advantageous at a particular time may well be disadvantageous at a later date. To forecast governmental action is (one is led to believe) beyond even the scope of expert tax accountants, and the following calculations therefore relate only to the situation under the regulations in force in 1967.

(3) Even although this investigation of the effect of taxation is unsophisticated, it is very possible that it contains errors of comprehension and interpretation which may invalidate any conclusions reached.

21.02 The following areas are discussed:

(1) The effect of Corporation Tax on the total distributable income

from The Farm run as a Limited Company, compared to the sum of gross incomes from the six farms, assuming that these are run by 'Sole Traders' (Section 20.05).

(2) The effect on the above calculation of retaining profits for capital expansion (Section 20.06).

(3) The effect of running the individual farms as Limited Companies, instead of as Sole Traders (Section 20.07).

21.03 The assumptions applied in calculation tax liability, and the rates of taxation used (5, 6) are listed in Table 40

21.04 There are three basic forms of business organisation - Sole Traders, Partnerships, and Corporations, as illustrated in Figure Q. A group of people can only trade as a partnership or as a corporation. Since with the rather rare exception of the Limited Partnership (in which only one partner accepts unlimited liability) all the partners can personally be held liable for the debts of a partnership, it would not be acceptable to run 'The Farm' under a partnership agreement.

It would probably be most suitable to run The Farm as a Private Company, limited by shares. It would also be a 'Close' company, since fewer than five families would control it by holding between them more than 50% of the shares.

TABLE 40

Personal allowance + child allowance + insurance etc. = £500/year/man

Earned income allowance (Income Tax) = $^2/_9$ of first £4005 + $^1/_9$ of next £5940. Assumed to Apply to total gross income

Earned income allowance (Surtax) = A sum which in addition to personal and income tax earned income allowances will reduce the income figure to £2000 or less, subject to a maximum allowance of £2000.

Income Tax rate	- first £100	of taxable income	@ 4/-	per £1	(20.0%)
"	- next £200	" "	@ 6/-	per £1	(30.0%)
"	- remainder	" "	@ 8/3	per £1	(41.25%)
Surtax rate	- first £2000	of surtaxable income	@ 0/0	per £1	(0.0 %)
" "	- next £500	" "	@ 2/-	per £1	(10.0%)
" "	- " £500	" "	@ 2/6	per £1	(12.5%)
" "	- " £1000	" "	@ 3/6	per £1	(17.5%)
" "	- " £1000	" "	@ 4/6	"	(22.5%)
" "	- " £2000	" "	@ 6/6	"	(32.5%)
" "	- " £2000	" "	@ 7/6	"	(37.5%)
" "	- " £2000	" "	@ 8/6	"	(42.5%)
" "	- " £3000	" "	@ 9/6	"	(47.5%)
"	- remainder	" "	@ 10/-	"	(50.0%)

Corporation Tax: 40% of (Gross Profit less Directors remuneration allowance)

Directors' Remuneration Allowance: First director £4000; Other directors £3000 each, subject to a maximum allowance of £13000, or 15% of gross profit.

Profit Distribution: Except by special arrangement, at least 60% of the net of C. Tax profit must be either (a) Distributed as dividend (b) Paid to directors as additional salary (c) Subjected to taxation at 41.25%.

TABLE 40: ASSUMPTIONS AND TAXATION RATES USED IN CALCULATING TAX LIABILITY.

FIGURE Q

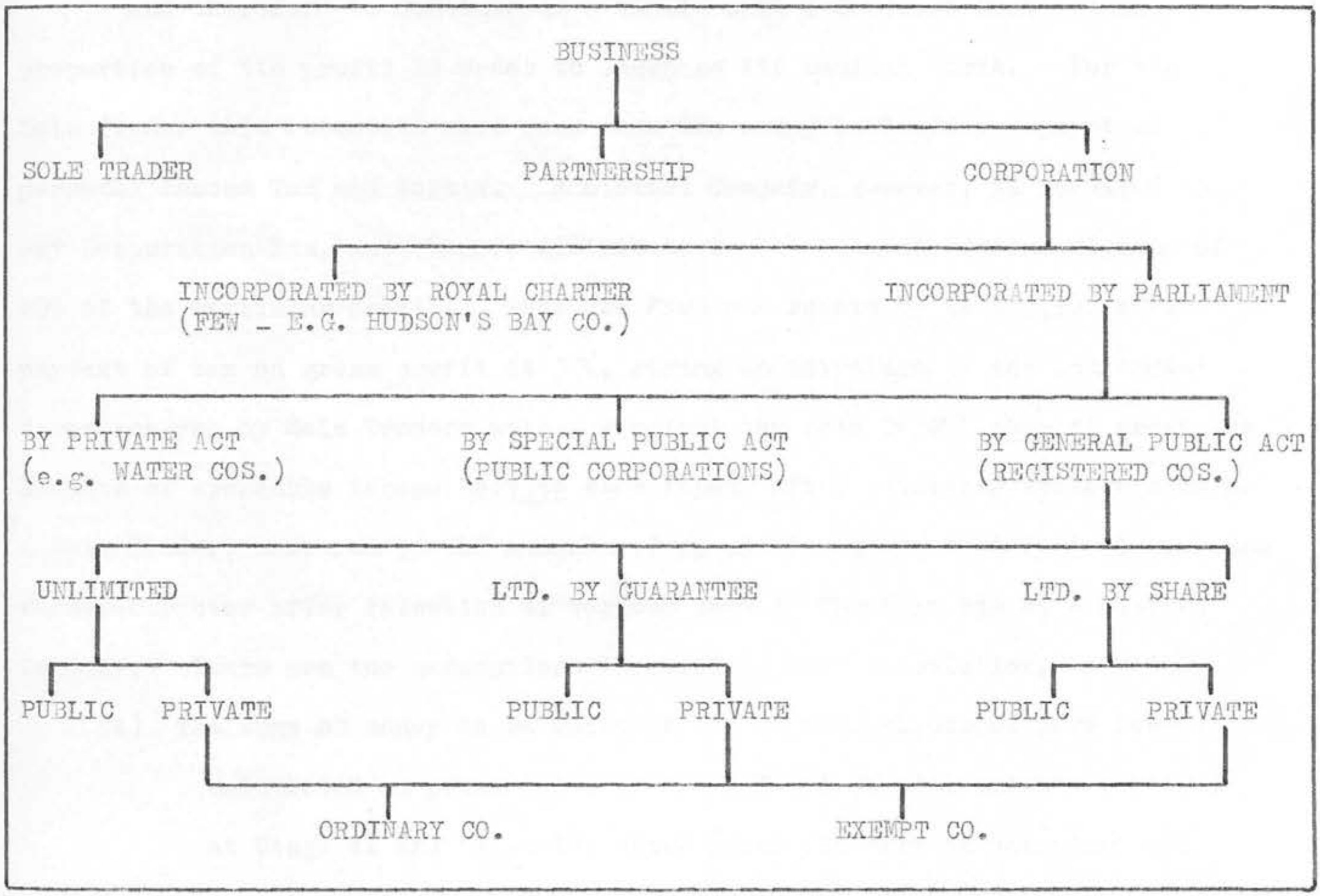


FIGURE Q FORMS OF BUSINESS ORGANISATIONS

21.05 If The Farm is run as a Limited Company then its total distributable profit 'N' $= G - ((G - \cdot 15G) \times 0.4) = 0.66\ G$ when the gross profit 'G' $\geq$ £86,667. Thus with a gross profit of £88261 (See Section 20.07), The Farm would have to pay 34% of its profit (£30,009) as Corporation Tax, leaving £58,252 for distribution to the six farmer-directors. This is £16,639 less than the total of the optimal profits (£74891). Thus, if all available money were to be distributed, the individuals would lose by taking part in an amalgamation, in comparison to the income they could make from their present businesses under the assumptions discussed in previous sections of this study.

21.06 It can be said of a business, that to stand still is to go backwards, and therefore to continue as a viable unit a business must retain a proportion of its profit in order to increase its capital worth. For the Sole Trader this retention must come from the money left after payment of personal Income Tax and Surtax. A Limited Company, however, is required to pay Corporation Tax, and then to distribute to it's shareholders a minimum of 60% of the remaining profit. Thus The Farm can retain up to £23,301 after payment of tax on gross profit at 34%, giving an advantage if the individual farms are run by Sole Traders with a marginal tax rate > 34%. Table 41 shows the amounts of spendable income left to each farmer after retaining various sums as a Sole Trader, compared to the amounts of spendable income distributable to each farmer-director after retention of various sums by The Farm run as a Limited Company. There are two assumptions involved in this calculation.

(1) The sums of money to be retained for capital expansion have been calculated as percentages of the Initial Capital amounts required at Stage II and Stage IV, which gives The Farm an advantage not derived from the method of taxation, since it produces a better 'return on capital' than the average for the six farms.

(2) The amounts of money 'paid' to each director from The Farm, after payment of Corporation Tax and retention of a proportion of profit, are in the same ratio to the total sum available as the individual farm profits at Stage II are to the total of Stage II profits. e.g. For F1, the amount paid from The Farm = Total sum available x 15091/74891. This is purely a convenience, for as will be discussed later, one of the major problems in implementing this type of co-operative action would be to agree on an equable method of calculating the distribution of profit.

TABLE 41

FARM	INL. CAP	G. INC.	POST I. TAX	SPENDABLE AMOUNTS AFTER RETAINING % OF PROFIT AS CAPITAL 1%	2%	4%	7%
F1 (a)	55679	15091	7125	6569	6012	4898	3228
F1 (b)		11738	6449	6310	6171	5849	5191
F2 (a)	73134	14993	7110	6378	5647	4184	1990
F2 (b)		11662	6430	6291	6154	5896	5169
F3 (a)	45536	10376	6092	5636	5181	4270	2904
F3 (b)		8071	5206	5044	4870	4519	3934
F4 (a)	29425	13060	6746	6452	6157	5569	4686
F4 (b)		10158	6034	5879	5701	5317	4684
F5 (a)	70678	17482	7442	6736	6029	4615	2495
F5 (b)		13598	6860	6730	6600	6294	5727
F6 (a)	27334	3889	2891	2618	2345	1798	978
F6 (b)		3025	2304	2212	2220	1934	1657
TOT (a)	301786	74891	37406	34389	31371	25335	16282
TOT (b)	262293	58252	33283	32466	31716	29809	26362

(a) Separate farms run by Sole Traders

(b) Director of The Farm receiving an amount of the distributable income of the Limited Company, in proportion to his previous gross income at (a).

TABLE 41: COMPARISON OF THE POTENTIAL SPENDABLE INCOMES OF INDIVIDUALS BEFORE AND AFTER AMALGAMATION, AT VARIOUS RATES OF PROFIT RETENTION.

Table 41 shows that farmers F1, F2 and F5 would have more spendable income as directors of The Farm when its capital is increased by 2% out of profits than as sole traders increasing their own capital by 2%. Farmers F3 and F6 would have an increased spendable income at 4% retention, and farmer F4 at 7% retention. These variations arise because the higher the Stage II return on capital compared to the return on capital from The Farm at Stage IV, the smaller relatively is the amount 'lost' by retention, while the greater the Stage II gross income, the higher is the marginal individual tax rate as a Sole Trader and therefore the greater the advantage of retaining profits after Corporation Tax only.

Therefore, if the assumptions (1) and (2) noted above are accepted, it would be to the advantage of all the farmers except F4 to amalgamate if capital had to be increased at a rate $\geq$ 4% per year. The 'cost of living' increase is currently (1967) estimated at 3%-4% per year.

21.07 So far, it has been assumed that the six farms are run as Sole Trader businesses. There is legally no reason why they should not be run as Limited Companies, thus gaining the profit retention advantages discussed above. With one director, there would be no Corporation Tax payable on the first £4000 of gross profit, so that if no profits were retained in the business, the tax load up to this level of profit would be the same whether as a company or as an individual, since all of the £4000 would be subject only to income tax. Above this level both corporation tax and income tax (and surtax) would be levied, and the effect of paying corporation tax before arriving at the income on which personal tax is assessed is simply to reduce, by the amount of corporation tax paid, the sum on which income tax is paid. i.e. Spendable income is reduced by (C - CR) where C = Corporation tax paid, and R = marginal rate of personal tax over the last £C of income as a sole trader. An increase in the directors' remuneration allowance would reduce the disadvantage, and the need for retention of profits would make the Limited Company more advantageous. Figure R indicates the amounts of profit retention which would result in identical levels of spendable income from given gross profits whether a business is run by a Sole Trader or as a Limited Company with two directors. It is affected by change points in allowances and taxation rates, and the required profit retention for breakeven falls off at higher gross profit levels because the marginal personal tax rate increases, so that (C - CR) becomes smaller. Table 42 gives the exact profit retention required for each of the six farms.

TABLE 42

FARM	GROSS PROFIT	PROFIT RETAINED	100 x P. RET./I.C.	SPENDABLE INCOME
F1	15091	875.2	1.57	6250.2
F2	14993	874.5	1.20	6234.9
F3	10376	833.0	1.83	5258.8
F4	13060	824.1	2.80	5922.1
F5	17482	822.5	1.16	6619.8
F6	3889	0	0.00	2891.3

TABLE 42 PROFIT RETENTION PER FARM TO OBTAIN IDENTICAL SPENDABLE INCOMES AS SOLE TRADER AND AS LIMITED COMPANY WITH 2 DIRECTORS.

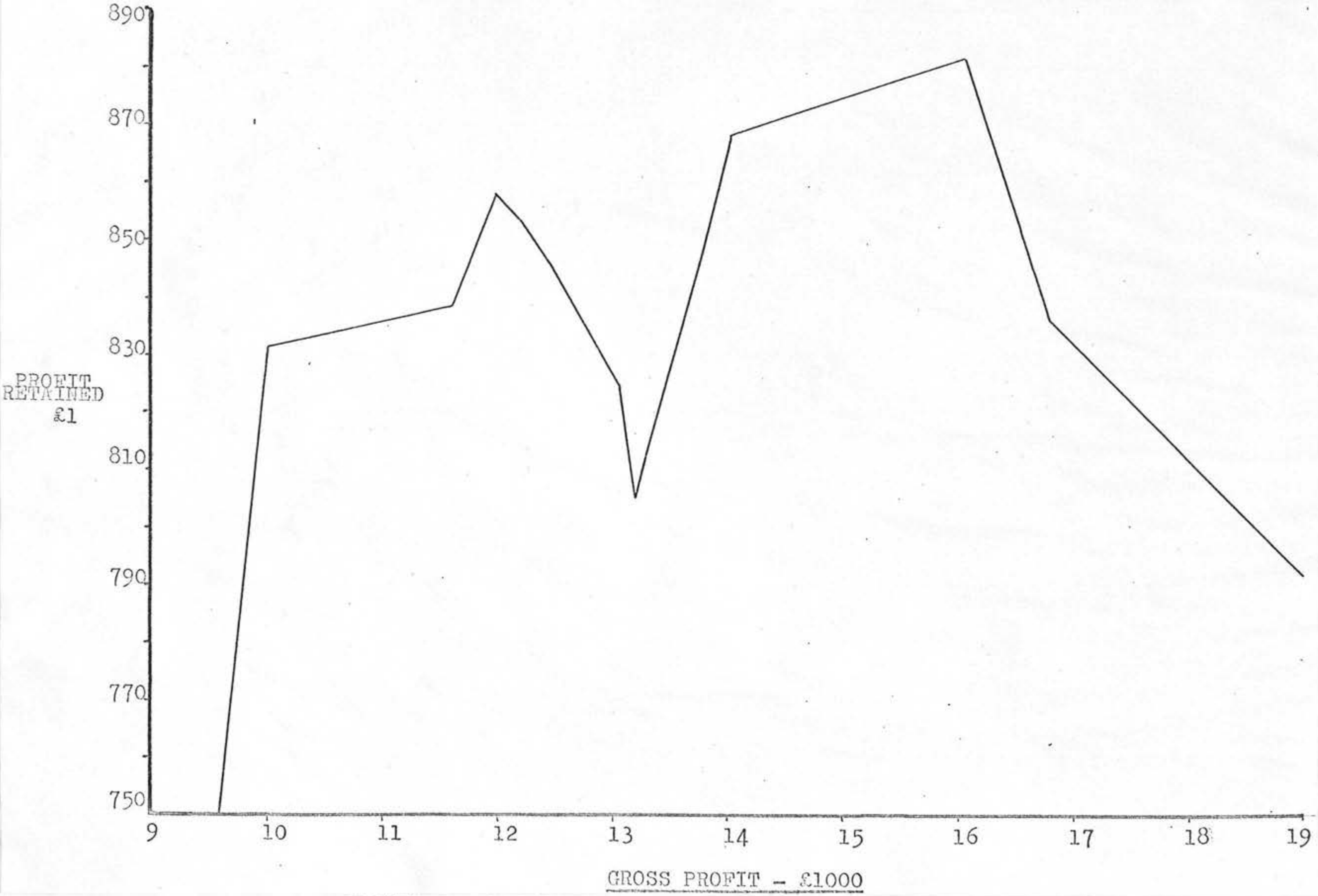


FIGURE R: PROFIT RETENTION TO GIVE IDENTICAL SPENDABLE INCOMES AS A SOLE TRADER OR AS A LIMITED COMPANY.

The calculation for Farm F5 is as follows:

	LTD. CO.	SOLE TRADER
Gross Profit	17482	17482
Dir. Rem. All.	7000	
C. Tax	4192.8	
Retained	822.5	
Pers. Inc.	12466.7	17482
Pers. All.	500.0	500
E. Inc. All.	1550.0	1550.0
Inc. Taxed	10416.7	15432.0
Inc. Tax	4253.1	6322.0
S. Tax E.I.A.	2000.0	2000.0
Surtax	1593.8	3717.8
I. Tax + S. Tax	5846.9	10039.8
Net of Tax	6619.8	7442.2
Retained		822.5
Spendable	6619.8	6619.7

The individual farms as a whole have a considerable advantage over a single company farming the 2811 acres, in that even with one director per farm the total of directors' remuneration allowances is £23889 (F6 has only £3889 profit) compared to £13239 (15% of £88261) for The Farms. With one director per farm, the sum of post C. Tax profits from the six farms is £54,490 from a gross profit of £74891. With two directors per farm the sum of post C. Tax profits is £60490, compared to the post C. Tax profit of £58252 from 'The Farm". Thus if the six farms were each run as Limited Companies with two directors, it would be financially disadvantageous for these farms to be run as one Company, whether or not any profits were retained.

21.08 As mentioned earlier, it is difficult to find a suitable basis on which to divide the profit from The Farm, assuming that none of the farmers would agree to amalgamation if it were to his disadvantage.

Summarised below are factors which might be taken into account in assessing the applicability of methods of profit distribution (The cost of borrowing Initial Capital at 9% has been met before arriving at the Gross Profit).

FARM	INIT. CAP.	GROSS PROFIT	100 G.P./I.C.	ACRES
F1	55679	15091	26.9	443
F2	73134	14993	20.5	542
F3	45536	10376	22.7	403
F4	29425	13060	44.3	500
F5	70678	17482	24.7	626
F6	27334	3889	14.2	297
The Farm	262293	88261	33.6	2811

Distribution on the basis of share capital would be unsatisfactory if the farmers concerned could provide all the capital required, since although the 'return on capital' for The Farm is better than for any of the individual farms except F.4., less capital is required and the Stage II rates of return vary, so that none of the farmers would be able to employ all his capital in The Farm, and on the capital that is employed, some would gain greater advantage than others. Assuming that each farmer were allowed to contribute to The Farm 86.9% (262293 x 100/301786) of his present capital and that a sum equal to the total of their gross individual profits were distributed on the basis of £28.5/£100 invested, then the distribution compared to present gross incomes would be:

	PRESENT G. PROFIT	SHARE FROM THE FARM	DIFFERENCE %
F1	15091	13817	-8.44
F2	14993	18149	+21.05
F3	10376	11300	+8.91
F4	13060	7303	-44.08
F5	17482	17539	+0.33
F6	3889	6783	+74.41
TOT.	74891	74891	

If, as is much more likely, each farmer owned only a part of the capital used in his farm, and he contributed this amount towards capitalising The Farm, then the distributable profit would be divided into fewer shares, and in a pattern which wuld be related only to the personal wealth of the individual farmers. Those farmers using a high proportion of borrowed money would lose the profit they make on borrowing that money as individuals.

An equal division of 1/6 of The Farm profit to each farmer would obviously be to the disadvantage of some, and distribution as salary payment relative to the worth or contribution of each man to the success of the business would involve the extremely difficult and probably embarassing task of putting a value on each man. Again, it would be to the disadvantage of some.

The Stage II and Stage IV profits are calculated allowing for a rental payment of £10/acre for all land regardless of type. Since the Stage II profits assume an equal standard of husbandry ability (standard yield data) and are all arrived at by mathematical maximisation of the farm margins from existing resources but with no limit on the availability of capital, they could in fact be regarded as measurements of the value of particular combinations of these resources when separated from human variation - the true rental value of the farms. With six farms, a value can be calculated for six resource variables

- e.g. one acre of each of the five types of land, and one hundred square feet of buildings. If there were more farms in the group, a greater number of variables could be quantified.

It is possible therefore that in practice, The Farm profit could be distributed according to a formula based on such a calculated rental value, plus payment for owned capital, plus a salary which might be derived from the difference between the actual attained profit on each farm and the maximum profit possible using the same amount of capital (See Section 18.0). Recompense would then be based on the three things which each farmer controls and would bring with him into the amalgamation - his farm, his money, and his ability.

LIST OF PUBLICATIONS REFERRED TO IN PART THREE (RESULTS)

1. Kerr, H.W.T. - Analysing the Use of Labour and Machinery. Farm Management Notes No. 35, University of Nottingham, Department of Agricultural Economics.

2. Farm Mechanisation - February 1966 and December 1966

3. Farm Mechanisation and Buildings - September 1967 and November 1967

4. MacHardy, F.V. - An Investigation of the Application of Programming Techniques to Farm Management Problems - Ph.D Thesis, Edinburgh School of Agriculture, 1965.

5. Board of Inland Revenue - P.A.Y.E. Coding Guide 1966-67.

6. Board of Inland Revenue - Surtax. Explanatory Notes No. 700 (Feb. 1967).

PART FOUR

SUMMARY AND DISCUSSION

22.0 Summary and Discussion

22.01 This study has attempted to answer the question stated in Section 8.01 - 'Does voluntary co-operative amalgamation of farms pay?', by examining the possible financial effect of amalgamation on a group of fairly prosperous arable farms.

22.02 Whether the answer is 'Yes' or 'No' depends, possibly, more on the starting point than on the end result. Certainly, if the method of computation is accepted as valid, the resources available on the 2811 acre block are capable of producing a greater gross profit when farmed as one unit than when run as six separate farms. This is the 'after' part of the before and after comparison. There are, however, four possible 'before' situations

(1) The results that the farms are actually currently producing, subject to the full effect of the variation in personal ability, circumstances, and desires of the individual. These have not been considered, for reasons stated in Sections 8.01 and 8.02.

(2) This eliminates the effect of the stock and crop husbandry knowledge and ability of the individual and his skill in organising labour, by assuming that an acre of wheat on a particular type of soil will produce a known gross margin, regardless of which farm it grows on or which farmer is growing it. With standard data, the acre of wheat will take the same time for ploughing, sowing and harvesting, no matter which farmer is supervising the work. This situation is referred to in the study as STAGE I and produces a total gross profit from the six farms of £49,872. The total tenants' capital employed (also calculated using standard data) is £213,966.

(3) Further human variables are here removed by using Linear Programming to calculate the values of a series of variables (the possible farm

enterprises and optional resources) which will give the maximum value of a function of those variables (the farm gross profit) when the values of the variables are limited singly or severally by a series of constraints (cropping rotations, buildings etc.) In this case one of the constraints limits the amount of tenants capital to the amount calculated for (2) above. Thus the effect of each farmer's individual ability to discover the most profitable way to run his farm, his particular attitude to risks and his preferences for a particular way of life, all disappear in using a mathematical system and a common set of assumptions to calculate maximum profit farm plans. This is referred to in the study as 'Lim. Cap.' and produces a total gross profit for the six farms of £59,242, using £214,094 of tenants' capital (£128 higher than at (2) - see Section 18.01)

(4) The fourth 'before' situation complies with the farmers' suggestion that they are not limited by capital availability in carrying out any scheme which is financially sound. Farm plans were produced which, with reference to the standard data and assumptions, are the best ways of making money from the limited areas of land and buildings. This is referred to in the text as STAGE II, with a total gross profit of £74,891 and requiring £301,786 of tenants' capital. This result, compared to 'Lim. Cap.' implies either that the farmers are in fact working to a capital limitation, or that the unquantified factors of attitude to risk and to the net of tax return on marginal effort cause them to choose not to increase profit by employing more capital.

22.03 The total gross profits at (2), (3), and (4) above are compared below with the gross profit obtainable from The Farm

		TOT. GR. PROFIT	INCREMENTS
(2) Stage I	: Present systems, standard data	49872	
(3) Lim. Cap.	: Opt. systems, Stage I capital	59242	
(4) Stage II	: Opt. systems, no capital limit	74891	+29019
Stage IV	: Opt. system for The Farm	88261	+13370

Calculations shown in Section 21.07 suggest that it would probably be advantageous for the individual farms to be run as Limited Companies, and it would also seem that The Farm must be a Limited Company since it involves several people sharing in the business, and individual liability for the debts of The Farm would not be acceptable. In this case, if each individual farm had two directors, and The Farm had six directors, the gross profits shown above would be subject to Corporation Tax after deducting directors' remuneration allowances of up to £7000 per present farm, leaving the distributable sums shown below.

	G. PROFIT	DIR. REM.	C. TAX	DISTRIBUTABLE
(2) Stage I	49872	35806	5626	44246
(3) Lim. Cap.	59242	38889	8141	51101
(4) Stage II	74891	38889	14401	60490
Stage IV	88261	13239	30009	58252

In Section 21.07 the Stage IV net profit was compared to the best possible result from the six separate farms (Stage II, with the farms run as Limited Companies so that The Farm had no advantage in profit retention), and was found to be £2238 lower than the total net of C. Tax profit from the six farms. Whether (a) The six farmers could, given the motivation, produce the Stage II results on their own farms or (b) If their present performance is correctly depicted by Stage I, they could as a group produce the Stage IV result, is open to opinion.

There is one other factor which might be considered in deciding whether the amalgamation is likely to be financially advantageous. That is, that expansion would be more easily brought about, not due to any taxation advantage, but because land would be more easily obtained. For example, if a 400 acre farm became available, it would be much more easily absorbed by The Farm than by any of the existing farms. The equivalent expansion for one of the existing farms would be 70-80 acres. A farm of 400 acres is likely to be cheaper per acre than one of 75 acres and would be more likely to have usable buildings (e.g. with capacity for sufficient stock to employ at least one man fully) than would the 75 acre holding. In an area of fairly large arable farms more 400 acre farms may become available, than 75 acre farms.

22.04 The results produced by Dixey and Maunder (Ref. (30), Part One) can in principle be compared to those produced in this study, in that they were produced by basically the same method, and also compare the net income from a given area of land before and after the amalgamation of the farms on it.

Dixey and Maunder (a) applied standard data to existing farm systems to produce a standardised margin - in their case, to three farms typical of the area. This is comparable to STAGE I of this study.

(b) Replanned each of these three farms, using the same standard data, to produce an improved profit. This is comparable to STAGE II.

(c) Constructed average cost curves to determine the optimum farm size so that the area could be suitably re-structured. This was not necessary in the present study since the intention was to consider the amalgamation of all the farms in an area into one, rather than to study economies of size or to determine optimum size.

(d) Compared the net income from 27 replanned farms of 125.3 acres average with the net income from 11 farms of 307.5 acres average. This is comparable in essence to the comparison of the margin from 6 replanned farms of 468.5 acres average (Stage II) with the margin from 1 farm of 2811 acres (Stage IV).

In spite of wide divergencies between the two studies in area, farm type (dairying in Dixey and Maunder's case) and farm size, there is similarity in the results in that in both cases the major part of the increase in margin was due to cost reduction rather than an increase in Gross Margin, as is shown below:

DIXEY AND MAUNDER

	PRESENT	PLANNED	% CHANGE	Change / N.Income Change x 100
Total Gross Margin	92396	96117	+ 4.03	38.3
Total Fixed Costs	84279	78279	- 7.12	61.7
Net Income	8117	17838	+119.8	

THIS STUDY

	STAGE II	STAGE IV	% CHANGE	CHANGE / N.INCOME CHANGE x 100
Total Gross Margin	198554	200587	+ 1.02	15.3
Total Fixed Costs	123627	112326	- 9.14	84.7
Net Income	74927	88261	+17.8	

22.05 If it is accepted that The Farm must be run as a Limited Company in order to give security to the participants then the comparison of the distributable amount (i.e. after Corporation Tax but before personal tax) from The Farm of £58252 (see Section 21.05) with the total sum of £74927 before personal tax which the six farms can produce is unlikely to encourage amalgamation. As discussed in Sections 21.06 and 21.07 there are various possible assumptions and counter-assumptions by which the amalgamation of the six farms might be made financially reasonable, but basically taxation is against it and one is left trying to find ways to make it worthwhile, rather than having shown that it is worthwhile. Although the Agricultural and Horticultural Co-operation Scheme was intended to assist small farmers to operate more efficiently (The Development of Agriculture, H.M.S.O. Cmnd. 2738, August 1965) farms and farmers of the type involved in this study would nevertheless be eligible for considerable grant aid. Also, there is continual governmental pressure on farming and farmers in general, by education, exortation and Price Review negotiations, to increase efficiency. It therefore seems a pity that a structural reorganisation which could increase the gross profit (Output less Inputs) from an area of land by 17.8% (from £74927 to £88261) should be invalidated by the policies of another governmental department.

22.06 There are many areas within and related to this study which could usefully be improved upon or subjected to further investigation. One question which is obviously pertinent is "What would be the conclusions on reorganisation, profit change, and tax effect if a similar study was carried out with a group of small farmers? Could they as a single business acquire sufficient additional capital and increase in efficiency enough to produce employment and an increase in income for each member of the group?"

Two unresolved problems which are considerably interrelated are:

(a) A definition of the possible executive and managerial tasks within the type of co-operative amalgamation or near amalgamation described, and the division of these, at various points on the scale of business size, into (i) Vital (ii) Useful and profitable.

(b) The calculation of a system of remuneration of the participants in such a co-operative venture. This would have to equate to the resources, ability, and time given by each person to the whole and also to the amount of responsibility devolving upon him, and would have to give each person a financial incentive to become involved in such a venture. There are, of course, many non-material incentives and disincentives, but at least the financial ones can be quantified.

There are possible managerial advantages in farm amalgamation. If the management function of the six individuals was related to enterprises instead of, as at present, to land areas, labour organisation would be easier, delegation of responsibility would be simpler and it would therefore be considerably easier for individual managers to get time off. Management division by enterprises does raise one problem in that there are six men and basically only three enterprises - cash roots, cereals, and stock. This could, however, be turned to advantage and probably profit since there are several management functions which in farming tend to get less attention than they should.

One man might take responsibility for marketing, and could well extend it beyond the point to which any of the individual farmers have time to. As an example, seed potatoes sent to the south of England by farmer F3 were claimed by the buyer to be diseased. Although they were healthy when dispatched, he had no time to check on the buyers' complaint due to pressure of spring work, and so had to agree to a substantial price reduction.

A second man could be very usefully employed in keeping the company abreast of technical developments by sifting the considerable volume of new information published (which many farmers put aside for perusal on the rainy day which never comes), by attending relevant demonstrations and by making enquiries aimed at finding the solution to particular problems in the business.

The third man could be responsible for recording and planning in order to advise the group in policy decisions. Each man of the six could also act as relief for one other manager.

It is interesting that in the "Report on Group Development in Agriculture" (Produce Studies Limited - Ref. (2), Part Two) it is noted that in production groups this type of management specialisation is a not usual development. Nevertheless, the idea of giving control of part of their own farm to someone else was not attractive to three members of the group, which exemplifies what is possibly the greatest deterrant to amalgamation - loss of freedom - the problem of having to act against one's wishes because of a majority decision, of having to obtain the agreement of others before putting thought into action - in short, the problem of co-operating. The reaction of farmer F2 to the idea of running a farm with five others was "I wouldn't mind co-operating - if I were the boss". To this, farmer F4 replied "I wouldn't mind having you for a boss, but you'd have to be damn good". These two quotations probably sum up the problem fairly well - group action could be indecisive because no one person is in a position to take quick decisions and to enforce his decisions, and men who have been accustomed to making their own decisions would not take easily to instruction.

Although it is probable that the amalgamation of this group of farms would produce financial advantages both short term (spendable income) and long term (expansion), and also possibly managerial advantages, it will be remembered that a large part of the increase in profit in this study, from Stage II to Stage IV, is due to a reduction in the cost of the labour/machinery complex.

There is considerable evidence to show that much of the financial benefit from farm amalgamation accrues by economies of size reducing power and labour costs per unit of output. This occurs in two ways - by using larger machines with a lower unit output average cost potential, and by operating machinery at nearer to full capacity, thus again lowering average cost per output unit. Labour cost may also be reduced if larger machinery is used, by increasing output per man hour. Therefore it might be possible to co-operate in machinery purchase and use, and in labour use, rationalising cropping as much as is feasible to derive the fullest possible savings from labour/machinery co-operation, and thus to increase the overall profit by almost as much as by amalgamation, without having to take the evidently objectionable step of 'losing identity'.

Although an integrated planning of enterprise size and machinery complement to produce the maximum net income (i.e. complete farm planning as in this study) may frequently be required, there are also many occasions (e.g. co-operative single crop growing, or situations where the cropping programme is pre-selected), where selection of the minimal cost labour-machinery complex for a specific task would be sufficient. MacHardy (Ref. (13), part Two) suggests a method of doing this using Lagrange Multipliers but this method appears to be limited to single man or single team operations. Such a selection could be approximated using the type of gang-work chart described by Kerr (Ref. (1) Part Three) and used in this thesis (Figures O and P), which is sufficiently flexible for the purpose, but cost minimisation would have to be done by trial and error, and would be very laborious. The Monte Carlo Simulation method (see for example J.B. Hardaker - Farm Economist 11, 4) might be a possible tool but has not been examined for this purpose as far as is known. Alternatively, the trial and error search of a gang work type chart could be formalised and computerised.

With regard to planning data, it has been shown (see Section 11.06) that the inclusion of labour availability in a linear programming model can have a marked effect on the solution, and also (see Appendix K) that variations in the loss of working time due to climatic factors can have a considerable effect on farm organisation and profit. Conversely, therefore, the accuracy with which loss of working time is defined must have a considerable effect on the accuracy of planning and profit prediction. Work done by Smith (Ref. (29) Part Two) on relating climatic factors to workable days for spring cultivations in the Midlands of England appears to be the most soundly based in this field, but extension to other seasons and areas is necessary.

A P P E N D I C E S

APPENDIX A

DESCRIPTION OF SOILS PRESENT ON THE GROUP OF FARMS

DRAINAGE SCALE

FREE: Never waterlogged - no mottling.

MODERATE: Only waterlogged for short periods after heavy rain- very slight mottling.

IMPERFECT: Waterlogged less than six months of the year - slight mottling.

POOR: Waterlogged more than six months of the year - strong mottling.

VERY POOR: Waterlogged twelve months of the year.

SOIL TYPES

KILMARNOCK (KK) Clay loam subsoil, 12" sandy clay loam topsoil - rock fairly near surface - small shallow areas and outcrops - well structured - smallish clods and good tilth. Drainage imperfect.

WINTON (WN) Similar to KK, but structure coarser - tilth more difficult. Drainage imperfect - subsoil easily puddled, may lead to waterlogging.

BROWNRIG (BG) Similar to KK but more loam and thus lighter. Drainage imperfect to moderate.

DREGHORN (DR) Sandy loam subsoil and sandy loam topsoil - structure good, but easily spoiled by bad handling - very good subject for irrigation. Tends to be short of potash. Drainage free.

SOIL TYPES (Cont.)

FRASERBURGH (FR)	Shelly sand - easily blown - chemical deficiency problems due to excess calcium. Drainage variable depending on subsoil, normally very free.
DARLEITH (DLb, DLt)	Very shallow (8"), developed direct on rock - many outcrops - subject to drought.
HUMBIE (HM)	Similar to WN - short of natural phosphate.
PEFFER (PF)	Silty fine sandy loam subsoil, fine sandy loam topsoil. Silt content very variable and moisture storage related to silt content, Silty patches act as heavy soil, but there is no clay in the soil, which brings chemical problems, so in this, it behaves as a sandy soil. Very short of potash. Structure very variable depending on silt content and treatment. Drainage imperfect.
CAULDSIDE (CU)	Silty clay loam over silty clay - texture makes cultivation difficult - get poaching and wheel slip. Very fertile if cultivated, but liable to panning and waterlogging. Drainage imperfect - poor.
ALLUVIUM (AL)	Very variable. Sandy loam - loam - silt loam (occasionally).
SMAILHAM (SM)	Sandy loam - drainage free.
MACMERRY (MY)	Similar to BG.

APPENDIX B

ENTERPRISE LABOUR COEFFICIENTS

Rates of work are based on those quoted by farmers involved in the study, and may vary according to soil type. Operational methods are also based on common current practice. An addition of 25% is made to all work times except for ploughing, beet singling and livestock. (See Appendix J).

NOTE: These labour coefficients were originally calculated using a small slide-rule, so there are inaccuracies.

The year is divided into five Periods, corresponding to the seasonal work pattern in East Lothian:

I	15th Feb. - 15th April	IV	16th August - 18th November
II	16th April - 20th June	V	19th November - 14th Feb.
III	21st June - 15th August		

HEAVY LAND

1)	MAINCROP POTATOES	HR/AC	MEN	MAN HRS.	TOTAL + 25%
I	Rotavate @ 5.6ac/8hr	1.43	1	1.43	
	Harrow @ 6 ac/1hr.	0.166	1	0.166	7.032
	Triple-K, twice, @ 23ac/8hr /run	0.690	1	0.69	
	Plant (4 row) @ 12ac/10hr	0.835	4	3.34	
II	Ridge, 6 runs @ 30ac/8½hr/run	1.67	1	1.67	2.09
III	Ridge, 1 run	0.279	1	0.279	0.837
	Spray, 2 runs @ 40ac/7½-8hr/run	0.39	1	.39	
IV	Lift @ 1.6 ac/8hr.	5.0	4	20.0	25.715
	Plough 25% @ 2.8 ac/8hr.	2.86	1	0.715	
V	Plough 75%	2.86	1	2.145	2.145

WHEAT (H)		HR/AC	MEN	MAN HRS.	TOTAL + 25%
I	Harrow	0.166	1	.166	
	Top Dress @ 6ac/1hr.	0.166	2	.332	0.831
	Roll @ 6ac/hr.	0.166	1	0.166	
II	Spray @ 40 ac/8hr.	0.2	1	0.2	0.25
III	NIL				0
IV	Combine and dry @ 17 ac/10 hr.	0.59	3	1.77	
	Harrow, three runs,	0.498	1	0.498	
	Drill, @ 28 ac/8hr.	0.286	1	0.286	
	Plough @ 3.2 ac/8hr.	2.5	1	2.5	
V	NIL				0

BARLEY (H)					
I	Triple-K	.345	1	.345	
	Drill	.286	1	.286	1.455
	Top-dress	.166	2	.332	
	Roll @ 40 ac/8 hr.	0.2	1	.2	
II	Spray	.2	1	.2	.25
III	NIL				0
IV	Combine and dry @ 14 ac/8hr.	0.571	3	1.713	2.855
	Plough 25% @ 2.8 ac/8 hr.	2.86	1	0.715	
V	Plough 75%	2.86	1	2.145	2.145

GRASS All Labour requirements are set against utilisation crops of silage, hay and grazing.

IRRIGATED GRAZING					
I	Top dress	0.166	2	.332	2.915
	Fence @ 1ac/hr.	1.0	2	2.00	
II	Top dress	0.166	2	.332	5.415
	Irrigate 1" @ 4 man hrs/ac in			4.0	
III	As Period II				5.415
IV & V	NIL				0

MEDIUM-HEAVY LAND

MAINCROP POTATOES (MH)		HR/AC	MEN	MAN HRS.	TOTAL + 25%
I, II and III - As for MC (H)					
IV	Lift @ 1.6 ac/8 hr.	5.0	4	20.0	25.0
V	Plough @ 3.2 ac/ 8 hr.	2.5	1	2.5	2.5
REDSKIN POTATOES (MH)					
I	Cultivate and plant as for MC (H)		6	5.626	7.72
	Ridge, 2 runs	.558	1	.558	
II	Ridge, 4 runs	1.116	1	1.116	1.395
III	Lift $\frac{1}{3}$ of crop @ 1.6 ac/8 hr.	1.666	4	6.666	8.32
	Dress $\frac{1}{3}$ of crop @ 18T (= 1.64ac)/8hr. (WET WEATHER)	1.626	6	9.756	12.19
IV	Lift $\frac{2}{3}$ of crop				16.64
	Dress $\frac{2}{3}$ of crop (WET WEATHER)				24.38
V	Box seed @ 15 ac/3 x $8\frac{1}{2}$ hrs. (WET WEATHER)	1.7	3	5.1	8.8
	Lay-in seed @ 35ac/2 x $8\frac{1}{2}$ hr.	0.486	4	1.943	
	Plough @ 3.2 ac/8 hr.	2.5	1	2.5	2.5
SUGAR BEET (MH)					
I	Harrow	0.166	1	0.166	5.17
	Roll	0.2	1	0.2	
	Fertilise	0.166	2	0.332	
	Rotavate	1.43	1	1.43	
	Plant	1.0	2	2.0	
II	Steerage Hoe 2 runs @ 11cc/$8\frac{1}{2}$ hr.	1.544	1	1.544	10.935
	Single @ 9 hr./ac.	9.0	1	9.0	
III	Steerage hoe - 1 run	0.772	1	0.772	0.967
IV	NIL				0

SUGAR BEET (MH)		HR/AC	MEN	MAN HRS.	TOTAL + 25%
V	Lift @ 3.2 ac/8 hr.	2.5	4	10.0	15.00
	Plough @ 3.2 ac/8 hr.	2.5	1	2.5	

WHEAT (MH) As Wheat (H)

BARLEY (MH) I, II, III as BARLEY (H)

IV	Combine and dry as barley (H)				2.14
V	Plough @ 3.2 ac/8 hr.				2.5

GRASS (MH) and IRRIG. GRAZING (MH) As on H.Land

FEED ROOTS (MH)

I	NIL				
II	As Sugar Beet (MH) Periods I and II				11.08
III	Steerage Hoe – 1 run				0.969
IV	NIL				
V	Plough @ 3.2 ac/hr.	2.5	1	2.5	27.5
	Lift as S.Beet but ½ rate (double yield)	5.0	4	20.0	

MEDIUM LAND

M.C. POTATOES (M) I. II & III as M.C.(H)	HR/AC	MEN	MAN HRS.	TOT. + 25%
IV Lift @ 1.8 ac/8 hr.	4.444	4	17.776	22.22
V Plough @ 3.6 ac/8 hr.	2.222	1	2.222	2.222
REDSKIN (M)				
I and II as RSK (MH)				
III Lift $\frac{1}{3}$ @ 1.8 ac/8 hr.	1.481	4	5.295	7.4
Dress $\frac{1}{3}$ as RSK (MH) (WET WEATHER)		6		12.19
IV Lift $\frac{2}{3}$				14.8
Dress $\frac{2}{3}$ (WET WEATHER)				24.38
V Plough @ 3.6 ac/h hr.				2.222
Box Seed as RSK.(MH) (WET WEATHER)		3		8.8
2ND EARLY POTATOES (M)				
I Cult. and plant as MC(H)		6	5.626	8.079
Ridge - 3 runs		1	0.837	
II Ridge - 4 runs		1	1.116	8.895
Irrigate $1\frac{1}{2}$" @ 4 mh/ac. in		1	6.0	
III Lift as MC(M)		4		22.22
IV NIL				
V Plough @ 3.6 ac/8 hr.		1		2.222
Box seed as RSK (MH) (WET WEATHER)		3		8.8
1ST EARLY POTATOES (M)				
I As 2nd E. (M)				
II Ridge-3 runs		1	0.837	8.546
Irrigate $1\frac{1}{2}$"		1	6.0	
III Lift @ 1.6 ac/8 hr.	5	4	20.0	25.0

1ST EARLY POTATOES (M) (Cont,)	HR/AC	MEN	MAN HRS.	TOT. + 25%
IV NIL				
V Plough @ 3.6 ac/8 hr.		1		2.222
Box seed as RSK (MH) (WET WEATHER)		3		.8.8
SUGAR BEET (M)				
I, II, III, IV As S.Beet (MH)				
V Lift As S.Bt(MH) + 25% for heavier crop	3.125	4	12.5)	17.847
Plough @ 3.6 ac/8 hr.			2.222)	
WHEAT (M)				
I, II, III as Wheat (H)				
IV Combine & Dry as Wheat (H)	0.59	3	1.77)	3.71
Harrow ½, two runs	0.166	1	0.166)	
Drill ½	0.143	1	0.143)	
Plough ½ @ 3.6 ac/8 hr.	1.111	1	1.111)	
V Plough and sow ½, as at IV				1.494
BARLEY (M)				
I, II, III, IV As Barley (MH)				
V Plough @ 3.6 ac/h hr.				2.222

GRASS (M) and IRRIG. GRAZING (M) As on H. Land

FEED ROOTS (M)

As for M.H. Land but plough @ 3.6 ac/8 hr.

LIGHT LAND

MAINCROP POTATOES (L)	HR/AC	MEN	MAN HRS.	TOT. + 25%
I, II, III, IV - As MC(M)				
V Plough @ 4 ac/8 hr.	2.0	1	2.0	2.0
REDSKIN POTATOES (L)				
I, II, III, IV - As RSK (M)				
V Plough @ 4 ac/8 hr.				2.0
Box seed - as RSK (M) (WET WEATHER)				8.8
2ND EARLY POTATOES (L)				
I, II, III, IV - As 2E (M)				
V As RSK (L)				
1ST EARLY POTATOES (L)				
I, II, III, IV - As 1E(M)				
V As RSK (L)				
SUGAR BEET (L)				
I, II, III, IV - As S. Beet (MH)				
V Lift as S.Beet (MH)	2.5	4	10.0	14.5
Plough @ 4 ac/8 hr.	2.0	1	2.0	
WHEAT (L)				
I, II, III As Wheat (H)				
IV Combine and Dry as Wheat (H)	0.59	3	1.77	2.212
V Harrow - 2 runs	0.332	1	0.332	2.773
Drill	0.286	1	0.286	
Plough @ 4 ac/8 hr.	2.0	1	2.0	
BARLEY (L)				
I, II, III, IV - As Barley (M)				
V Plough @ 4 ac/8 hr.				

GRASS (L) and IRRIG. GRAZING (L) As on H. Land.

THIN LAND

	HR/AC	MEN	MAN HRS.	TOT. + 25%

MAINCROP POTATOES (T) - As M.C. (MH)

WHEAT (T) - As Wheat (H)

BARLEY (T) - As Barley (MH)

GRASS (T) - As Grass (H)

LIVESTOCK

BARLEY BEEF	W.D. TIME	WET TIME
200 head = 1 man for ½ day = 0.02 hr/head/day, split between W.D. and WET time.		
I 61 days @ 0.02 = 1.12 hr (50% W.D.)	0.61	0.61
II 65 days = 1.30 hr (")	0.65	-
III 56 days = 1.12 hr (")	0.56	0.56
IV 95 days = 1.90 hr (40% W.D.)	0.76	1.14
V 88 days = 1.76 hr (30% W.D.)	0.528	1.232

PIGS

Assumed to take about the same time, per sq. ft. of stock, as Barley Beef on straw. Pigs - 13 sq. ft.; B.Beef - 25 sq. ft.

Labour for pigs 0.1 hr/unit of 10 pigs/day

	W.D. TIME	WET TIME
I NIL		
II 30 days @ 0.1 = 3.0 hr. (50% W.D.)	1.5	-
III 56 days = 5.6 hr. (")	2.8	2.8
IV 60 days = 6.0 hr. (40% W.D.)	2.4	3.6
V NIL		

WINTER FED CATTLE

200 cattle/man = 0.04 hr/head/day, but fed morning and evening so % in W.D. Time same as % of W.D. Time available.

	W.D. TIME	WET TIME
I 61 days @ 0.04 = 2.44 (67% W.D.)	1.635	0.805
II 31 days @ 0.04 = 1.24 (85% W.D.)	1.054	-
III NIL		
IV NIL		
V 88 days @ 0.04 = 3.52 (45% W.D.)	1.584	1.936

EWES

400 ewes/man = $\frac{3}{4}$ M.day/ewe or 60 hrs/unit of 10 ewes/year	W.D. TIME	WET TIME
I 33% of total time = 19.8 hr. (50% W.D.)	9.9	9.9
II 14% " " = 8.4 hr. (")	4.2	4.2
III 20% " " = 12.0 hr. (")	6.0	6.0
IV 13% " " = 7.8 hr. (")	3.9	3.9
V 20% " " = 12.0 hr. (")	6.0	6.0

18 MONTH FRIESIANS

Calves bought in Autumn, fat cattle sold in Spring, so winter work involves calf rearing from mid-October to mid-May, and also feeding mature cattle.

Work times are assumed to be:

0-2 mth. calves	-	120 calves/man	=	0.067 hr/calf/day
2-5 mth. "	-	$\frac{1}{2}$ time of B.Beef	=	0.01 hr/calf/day
5-7 mth. "	-	$\frac{1}{2}$ " W.Cattle	=	0.02 hr/calf/day
12-18 mth. cattle	-	As W.Cattle	=	0.04 hr/head/day

		WINTER I	WINTER 2	TOTAL	W.D.	WET
I	(15/2-15/4)	61 days @ 0.02 +	61 days @ 0.04 =	3.66	2.45(67%)	1.21
II	(16/4-20/6)	31 days @ 0.02		= 0.62	0.527(85%)	-
III	(21/6-15/8)	Nil		= -	-	-
IV	(16/8-18/11)	30 days @ 0.067 +	30 days @ 0.04 =	3.21	2.14(67%)	1.07
V	(19/11-14/2)	30 days @ 0.067 +	88 days @ 0.04 =	6.11	2.75(45%)	3.36
		58 days @ 0.01				

OTHER ACTIVITIES

SILAGE (1 cut)	HRS/UNIT	MEN	MAN HRS.	TOT + 25%
I Top dress @ 6ac/hr	0.166	2	0.332	0.415
II Mow and turn @ 1ac/hr	1.0	1	1.0	6.665
Lift grass @ 1ac/hr	1.0	4	4.0	
Top Dress @ 6ac/hr.	0.166	2	0.332	
III Fence - est. @ 1 hr/acre	1.0	2	2.0	2.5
IV and V - NIL				
SILAGE (2 cut)				
I As for 1 cut				0.415
II "				6.665
III Mow and turn @ 1 ac/hr	1.0	1	1.0	7.915
Lift grass @ $1\frac{1}{2}$ ac/hr	0.75	4	3.0	
Top dress @ 6 ac/hr	0.166	2	0.332	
Fence	1.0	2	2.0	
IV and V Nil				
HAY				
I Top dress	0.166	2	0.332	0.415
II Cut and turn	1.0	1	1.0	2.25
Bale @ 20 ac/8 hr.	0.4	2	0.8	
III Stack bales @ 10 ac/8 hr.	0.8	3	2.4	5.915
Top dress	0.166	2	0.332	
Fence	1.0	2	2.0	
IV and V Nil				
GRAZING				
I Top dress	0.166	2	0.332	2.915
Fence	1.0	2	2.0	
II Top dress				0.415
III, IV, V - NIL				

POTATOES SOLD AUTUMN (10T)

	HRS/UNIT	MEN	MAN HRS.	TOT + 25%
I, II, III, IV Nil				
V Dress 10.526 T @ 18T/8hr = 0.4444 hr/ton (WET WEATHER)	4.6782	8	37.426	46.782

POTATOES SOLD SPRING (10T)

I Dress 11.2048T @ 18T/8hr. (WET WEATHER)	4.9549	8	39.6393	49.549
II, III, IV, V Nil				

BEET TOPS FED (10T)

I - IV Nil				
V 2 men x 15hr/wk. x 12 wks. = 52 ac. @ 7T/ac.	110.0	1	10.0	12.5

STRAW (10T)

I - III Nil				
IV Bale @ 4T/hr	2.5	2	5.0	15.63
Stack @ 2½ ac/hr @ 1.6 T/ac.	2.5	3	7.5	
V Nil				

F.Y.M. (100T)

Four variables - Periods I, III, IV and V

Labour required quoted as 5.2 mhr/12T and 16 man minutes/Ton by two sources. (WET WEATHER)	35	1	35	44

APPENDIX C

ACTIVITY MARGINS AND COSTS

MAINCROP POTATOES (H, M-H, M, L, T)

Disposal of the crop is effected by two sale activities. Variable costs of growing are the same on all land types.

			YIELDS
Seed	: 25 cwt. @ £18.5/ton	= 23.15	
Fert.	: 8 cwt. @ £24/ton	= 9.60	(H) 10 Tons/acre
Blight	: 3lb dust @ £0.6/lb	= 1.80	
Burning:		= 1.70	(HM) 11 Tons/acre
Cas. Lab.:	25 hrs. @ £0.325/hr.	= 8.13	(M) 12 Tons/acre
P.M.B.	: Levy	= 3.00	(L) 10 Tons/acre
Misc.	:	= 1.00	(T) 8 Tons/acre
TOTAL Variable Costs		£48.38 per acre	

EARLY MAINCROP (REDSKIN) POTATOES (M-H, M, L)

Variables include sale of the crop at various yields. Costs are the same on all soils.

Seed	:	25 Cwt. @ £18.5/ton	= 23.15
Fert.	:	8 cwt @ £24/ton	= 9.60
Blight	:	$1\frac{1}{2}$ lb dust @ £0.6/lb	= 0.90
Burning	:		= 1.70
Cas. Lab.	:	25 hr lifting @ £0.325/hr.	= 8.13
Cas. Lab.	:	12.19 hr. dressing @ " "	= 3.95
P.M.B.	:	Levy	= 3.00
Misc.	:		= 1.00
Total Variable Costs			£51.43/acre

EARLY MAINCROP (REDSKIN) POTATOES (M-H, M, L) (Cont.)

OUTPUT

(MH)	=	11T @ 95% saleable	@	£14	=	£146.3
(M)	=	12T @ "	" @	"	=	£159.6
(L)	=	10T @ "	" @	"	=	£133.0

SECOND EARLY POTATOES (M, L)

Variables include sale of the crop at 9 Tons/acre @ £16/Ton = £145/acre on both Medium and Light Land. Variable Costs are the same on both soils except for fertiliser.

Seed	:	20 cwt. @ £24/ton	=	24.00
Fert	:	$7\frac{1}{2}$ cwt. @ £24/ton	=	9.00
Spray	:		=	1.50
Cas. Lab.	:	22.22 hr. @ £0.325/hr	=	7.22
Boxes	:		=	2.00
P.M.B.	:	Levy on $\frac{1}{3}$ acreage	=	1.00
Misc.	:		=	1.00

Total Var. Costs - MED. LAND £45.72/acre : Margin = £99.28

Plus $\frac{1}{2}$ cwt. fert @ £24/ton = 0.60

Total Var. Costs - LIGHT LAND = £46.32/acre : Margin = £98.68

FIRST EARLY POTATOES (M, L)

Variables include sale of the crop at 7 tons/acre @ £20/ton = £140/acre on both Medium and Light land. Variable Costs are the same on both soils except for fertiliser.

Seed	:	20 cwt @ £22/ton	=	22.00
Fert.	:	$7\frac{1}{2}$ cwt.@ £24/ton	=	9.00
Spray	:		=	1.00
Cas. Lab.	:	25 hrs. @ £0.325/hr.	=	8.13
Boxes	:		=	2.00

FIRST EARLY POTATOES (M, L) (Cont.)

Misc. :	= 1.00	
Total Var. Costs - MED. LAND	£43.13/acre : Margin = £96.87	
Plus $\frac{1}{2}$ cwt. Fert. @ £24/ton	= 0.60	
Total Var. Costs - LIGHT LAND	£43.73/acre : Margin = £96.27	

SUGAR BEET (MH, M, L)

Variables include the sale of the crop. Variable Costs are the same on all soils.

Seed	:	= 1.34
Fert.	: 9 cwt. @ £23/ton	= 10.35
Insecticide	:	= 2.00
Weed Spray	: 5 pts. @ £0.55/pt.	= 2.75
Salt	: 5 cwt. @ £4.9/ton	= 1.22
Total Variable Costs		£17.66/acre

OUTPUT

(MH)	- 12T @ £6.3/ton	= £75.6/acre
(M)	- 14T @ "	= £88.2/acre
(L)	- 12T @ "	= £75.6/acre

WHEAT (H, MH, M, L, T)

Crop disposal by two separate sale activities. Variable Costs of growing are the same on all land types.

				YIELD
Seed	: 3 bush. @ £42/ton	=	3.54	
Fert.	: $1\frac{1}{2}$ cwt. @ £17.7/ton	=	1.33	(H) 2.1 Tons/acre
Fert.	: 3 cwt. @ £12.0/ton	=	1.80	(MH) 2.1 " / "
Spray	: $3\frac{1}{2}$ pts. @ £0.2/pt.	=	0.70	(M) 2.0 " / "
Fuel	: Drier	=	0.60	(L) 1.6 " / "
Total Variable Costs			£7.97/ac.	(T) 1.6 " / "

BARLEY (H, MH, M, L, T)

Crop disposal by two sale variables, one feed variable, and obligatory inclusion in the diet of some stock. Variable Costs of growing are the same of all land types.

				YIELDS
Seed	: 3 bush. @ £32/ton	= 2.400		
Fert.	: 3 cwt. @ £22.15/ton	= 3.320	(H)	1.85 Tons/acre
Spray	: 2 pts. @ £0.9/gall	= 0.225	(MH)	1.855 " / "
Fuel	: Drier	= 0.450	(M)	1.85 " / "
		6.395	(L)	1.5 " / "
Less	: Subsidy	= 4.700	(T)	1.4 " / "
Total Variable Costs		£1.695/acre		

GRASS (H, MH, M, L, T)

'Grass' is a land using variable which instead of being used directly, supplies acre equivalents to a balance, for utilisation by 'Grazing', 'Hay', 'Silage (1 cut)' and 'Silage (2 cuts)'

			Acreage Equivalent from 3 acres
Seed	:	= 1.5	
Fencing:		= 2.0	(H) - 3ac. (M) - 2.8 ac. (T) - 2.5ac.
Totl Var. Costs		£3.5/acre	(HM) - 3 ac. (L) - 2.5ac.

IRRIGATED GRAZING (H, MH, M, L - F1 and F4 only)

Contributes directly to dairy cow grazing @ ½ acre/cow.

Seed	:	= 1.50
Fert.	: 6 cwt. @ £23.4	= 7.02
Fert.	: 6 cwt. @ £12.0	= 3.60
Fencing:		= 3.00
Total Variable Costs		£15.12

FEED ROOTS (MH, M)

Yield output converted to Starch Equivalent, Digestible Crude Protein, and Dry Matter supplying the three nutrient balances.

Seed :	= 0.71		YIELD
Fert. : 9 cwt. @ £23/ton	= 10.35	(MH)	25 Tons/acre
Total Variable Costs	£11.06	(M)	22 Tons/acre

GRAZING (Utilisation of Grass)

Fert. : 6 cwt. @ £23.4/ton	=	7.02
" : 4 cwt. @ £12.0/ton	=	2.40
Total Variable Costs		£9.42/acre equivalent

HAY (Utilisation of GRASS)

Fert. : 3 cwt. @ £23.4/ton	=	3.51
Fert. : 6 cwt. @ £12.0/ton	=	3.60
Twine:	=	1.00
Total Variable Costs		£8.11/acre equivalent

SILAGE - 1 CUT (Utilisation of GRASS)

Fert. : 4 cwt. @ £23.4/ton	=	4.68
Fert. : 4 cwt. @ £12.0/ton	=	2.40
Total Variable Costs		£7.08/acre equivalent

SILAGE - 2 CUTS (Utilisation of GRASS)

Fert. : 6 cwt. @ £23.4/ton	=	7.02
: 4 cwt. @ £12.0/ton	=	2.40
Total Variable Costs		£9.42/acre equivalent

POTATOES SOLD

(Autumn) Allowing for 5% brock, require 10.527 Tons grown to sell 10 Tons @ £15/ton

(Spring) Allowing for 7% shrinkage and 10% brock, require 12.048 Tons grown to sell 10 Tons @ £17/ton.

Brock potatoes contribute to nutrient balances.

GRAIN DISPOSAL

	AUTUMN	SPRING
Wheat sold	£22/Ton	£27/Ton
Barley sold	£19/Ton	£22/Ton
Barley bought	£20/Ton	£23/Ton
Barley fed	£0.25/Ton for milling.	

STRAW USED

Used as feed (barley straw) or as litter (barley and wheat straw) at a cost of £0.50/Ton for baler twine.

SOYA MEAL

Included as a protein supply at £44/Ton.

LABOUR

One man, normal working hours for one year - £750.0

One hour of overtime work (Dry Weather) - £0.3708

" " " (Wet Weather) - £0.3707

" " Casual labourer - £0.325

Supply of work hours per man:

	WDNT	WET NT	TOT NT	WDOT	WET OT	TOT. OT
Period I (15/2-15/4 = 60 days)	257.2	120.4	377.6	146.3	60.4	206.7
Period II (16/4-20/6 = 66 days)	357.3		357.3	348.9		348.9
Period III (21/6-15/8 = 56 days)	257.3	94.5	351.8	268.6	97.9	366.5
Period IV (16/8-18/11 = 95 days)	438.2	168.2	606.4	230.8	89.2	320.0
Period V (19/11-14/2 = 88 days)	224.1	272.3	496.4	89.6	108.8	198.4
			2189.5			1440.5

TRACTOR and TRAILER (MF-165, £1035 + £160)

1500 hrs/year running time assumed, allowing 7 years life (Culpin).

Depreciation = 1035/7 + 160/8 = 168.000

Repairs = 1500 x £0.01 x 1035/100 = 155.250

Fuel = 1500 hrs. x 0.65 g x £0.075 = 73.125

Oil = 1.000

£397.375

F.Y.M. (100 Tons per Period I, III, IV, V)

Based on cost (Culpin) of spreader working 200 hrs/year @ 6 Tons spread/hour

	PER YEAR	PER 100 TONS
Depreciation	43.8	3.65
Repairs	35.04	2.92
		£6.57

SILO-HORIZONTAL (1000 cu. ft.)

Capital cost per ton stored estimated at £6/Ton. Assuming that 1 Ton = 50 cu. ft. and that life is 12 years; annual cost = £10/1000 cu. ft.

SILO-TOWER (1000 cu. ft.)

Capital cost of tower estimated at £8/Ton stored + £1600 for unloading equipment for 800 Ton tower = £10/Ton @ 50 cu. ft./Ton and 10 year life = £20/1000 cu.ft./ year.

BARLEY BEEF (STRAW)

Calves are bought at 200 lb. L.W. (12-13 wks. old). Farmer F6 had accurate records showing average time from purchase to sale to be 279 days. Therefore the variable refers to one space occupied for one year, which is equivalent to a turnover of 1.308 animals/year.

BARLEY BEEF (STRAW) (Cont.)

			PER HEAD			PER SPACE	
Carcase	: 500lb @ £0.15	=	75.000		=	98.100	
Subsidy	: Av. of M and F	=	9.750	84.750	=	12.753	110.853
Calf	: 200lb @ £0.13125	=	26.250		=	34.335	
Conc.	: 5.261 cwt @ £44.5/Ton	=	11.706		=	15.311	
Vet.	:	=	3.981	41.937	=	5.207	54.853
MARGIN				£42.813			£56.000

FEED USE:

500 lb D.Wt. @ 57% K.O. = 877.2 lb. L.Wt.

Calf = 200.0 lb. L.Wt.

L.W.G. = 677.2 lb.

677.2 lb. L.W.G. @ 5.8 : 1 conversion = 35.07 cwt. feed

15% Protein Concentrate = 5.261 cwt.

85% Barley =29.809 cwt. x 1.308 = 1.95 Tons.

35.070

BARLEY BEEF (SLATS)

As above but in addition require 13 sq. ft. of slats. Capital cost estimated @ £1/sq.ft. - 10 year life = £1.3 per space/year which is deducted to give the margin per space of £54.7

18 MTH. FRIESIAN BEEF

Calf = 15.00	0.95 cattle @ $8\frac{1}{4}$ cwt. @ £9.5	=	74.456
Conc. = 13.60	Subsidy 0.95 @ £9.75	=	9.263
Vet. = 0.50	Less Haulage @ £0.5	=	0.475
Var. Costs £29.1			83.244
	Variable Costs		29.100
	Margin on 0.95		54.144
	Margin on 1.00		£57.0

WINTER FED CATTLE (Two cattle fattened per winter)

Sell @ 10 cwt. @ £9.5/cwt =	95
Buy @ 8 cwt. @ £9.0/cwt =	72
	23
Vet. and haulage	1.5
Margin per head	21.5
Margin per unit	43.0

SUMMER FED CATTLE

Sell @ 10 cwt. @ £9.0/cwt =	90.0
Buy @ 7.3 cwt. @ £10.0/cwt.=	73.0
	17.0
Haulage etc.	1.5
Margin	£15.5

EWES (10)

Lamb feed $1\frac{1}{2}$ cwt. @ £40	= 3.0	15 lambs @ £6.75 =	101.25
Vet. etc.	= 1.5	9 fleeces @ £1.0 =	9.00
Fencing (over 5 yrs.)	= 3.0	2 cast ewes @ £3.0=	6.00
Variable Costs	= 7.5	0.1 cast rams @ £5.0=	0.50
			116.75
		2.5 ewes @ £12.0	
		0.11 rams @ £30.0	33.30
			83.45
		Variable Costs	7.50
		MARGIN	£75.95

Ewe Feed: Barley feed for 6 weeks before lambing and 2 weeks after lambing, starting at 0.75 lb/ewe/day and rising to 2.0 lb/day = 0.344 Tons/10 ewes.

PIGS (10)

Bought as weaners for summer fattening to bacon in straw yards occupied in winter by Friesians and winter fed cattle.

Conc. :	0.656 Tons @ £42 =	27.552	Sell 9.8 pigs @ 200lb L.W. @ £16.3 =	159.740
Vet. :	=	2.000	Buy 10 pigs @ 40 lb @ £6.0 =	60.000
Variable Costs		29.552		99.740
			Less Variable Costs	29.552
			Margin	£70.188

Feed use : 1600 lb. L.W.G. @ 4.6 : 1 conversion = 3.28 Tons feed

20% Protein concentrate	= 0.656 Tons
80% Barley	= 2.624 Tons
	3.280

DAIRY COWS (SF)

Friesian cows cubicle housed, on self-feed silage

Vet.	=	3.50	927 gall milk @ £0.16 =	148.30
A.1./Bull	=	1.50	0.22 culls @ £60 =	13.20
Sawdust	=	0.40		
Misc.	=	0.70	0.85 calves @ £15 =	12.75
Housing	£75/cow, 10 yr.life =	7.50		174.25
Equip.	£25/cow, 5 yr.life =	5.00	0.25 heifers @ £120 =	30.00
Labour	80 cows/man @ £1200 =	15.00		144.25
		33.60	Costs	33.60
			Margin	£110.65

Feed Use: 96 lb silage/day; Other winter feed selected in computation
Summer: Feed for 1 gall/day @ 4lb Barley/gallon for 90 days from 1st July = 0.161 Tons.

DAIRY COWS (BYRE)

Vet :		= 3.50	927 gall @ £0.16	= 148.30
A.I./Bull:		= 1.50	0.22 culls @ £60	= 13.20
Misc. :		= 0.70	0.85 calves @ £15	= 12.75
				174.25
Housing :	£60/cow, 10yr. life	= 6.00		
Equip. :	£30/cow, 5 yr. life	= 6.00	0.25 heifers @ £120	= 30.00
Labour :	50 cows/man @ £1200	= 24.00		
				144.25
		41.70	Costs	41.70
			Margin	£102.55

Feed use: All winter feed selected in computation. Summer feed as for Cows (S.F.)

APPENDIX D

FARM MACHINERY PRICES

The following list includes all the machines which would probably be necessary in running a farm of the type investigated. As described in Section 16.02 of the text, the final planning model included only seven items although some of these comprise two of the machines listed below.

IDENTIFICATION KEY

K3	- Triple K spring cultivator	P	- Plough
H	- Zig-Zag harrows	M/T	- Grass mower + Tedder
F.D.	- Fertiliser distributor	P.P.	- Potato planter
R.	- Land roller	BK.	- Buckrake
D	- Grain drill	F.H.	- Forage harvester
M	- F.Y.M. spreader	B.L.	- Bale loader
BS	- Sugar beet seeder	B/Sl.	- Baler + bale sledge
Rot.	- Rotary cultivator	P.H.	- Potato harvester
Rg.	- Ridge plough cultivator	C	- Combine harvester
St.H.	- Steerage hoe	B.H.	- Sugar beet harvester
S.	- Crop sprayer	P.D.	- Potato dresser

MAKE	K3	H	F.D	R	D	M	BS	Rot.	Rg.	St. H.	S
Ferguson			£82		£440	£356	£260		£67		
Bamford					£194	£230					
Nicholson			£116	£300						£128	
Tasker			£268								
Lister		£52	£99				£206			£120	£227
McCormick					£435	£340					
Kongskilde	£53	£47									
Type (Cost	£53	£47	£135	£300	£440	£340	£206	£350	£67	£120	£140
Used (Size'	7'	18'	18'	24'	12'	160 cf.	5row	5'	5row	5row	18'

MAKE	P	M/T	P.P.	BK.	F.H.	B.L.	B/Sl.	P.H.	C.	B.H.	P.D.
Ferguson	£120	125/ 242	£240		£270+		£640	£860	£2040		
Bamford	£115	114/ 140					£645		£3115		
Nicholson		/155									
Tasker				£32							
Lister		105/ 139	£405		£304+	£88				£464	
McCormick						£100	£670		£2540		
Kongskilde		/143									
Type (Cost	£115	£255	£405	£32	£344	£88	£670	£860	£2040	£470	£850
Used (Size	2x14"	5'	4row	7'	60"		McC	1row	M788		Couch

APPENDIX E

ENTERPRISE SEASONAL CASH FLOWS

For the purpose of representing cash flow, the year has been divided into six periods of two months each. It is assumed that costs are met in the periods in which they are incurred, and that revenue is received in the period in which produced is disposed of. The six periods are:

1 = 1st March - 30th April	4 = 1st September - 31st October
2 = 1st May - 30th June	5 = 1st November - 31st December
3= = 1st July - 31st August	6 = 1st January - 28th February

There is also allowance for Valuation Capital - the value of equipment, stock, and crop on hand at 1st March. The total of the cash flow for the six periods is equal to the cost row entry for each activity, except for Initial Capital.

MAINCROP POTATOES

V.C.	= -
1) Seed + Fert.	= +32.75
2) P.M.B.	= + 3.00
3) Blight	= + 1.80
4) Burn, Casual	= + 9.38
5) Misc.	= + 1.00
6)	= -

E.M.C. POTATOES

V.C.	= -
1) Seed + Fert.	= +32.75
2) P.M.B.	= + 3.00
3) Sprays, $\frac{1}{3}$ Cas.	= + 6.68
4) $\frac{2}{3}$ Cas., Misc, Crop sale	=-137.30 (MH) -150.6(M); -124.0(L)
5)	-
6)	= -

2E. POTATOES

V.C.	= -
1) Seed, Fert, Spray	= +34.50(M); 35.10(L)
2) P.M.B.	= + 3.00
3) Cas., Crop sale	= -137.78
4) P.M.B. rebate	= - 2.00
5) Boxes, Misc.	= + 3.00
6)	= -

1st E. POTATOES

V.C.	= -
1) Seed, Fert, Spray	= +32.00(M); 32.6(L)
2) P.M.B., $\frac{1}{2}$ Cas.	= + 7.065
3) $\frac{1}{2}$ Cas., Crop sale	= -135.935
4) P.M.B. rebate	= - 3.000
5) Boxes, Misc.	= +3.000
6)	= -

SUGAR BEET		WHEAT	
V.C.		V.C. Aut.seed + fert	=+4.87
1) Seed, fert, spray, salt	=+15.66	1) Spring fert.	=+1.80
2) Insecticide	=+ 2.00	2) Spray	=+0.70
3)	= -	3)	= -
4)	= -	4) Drier fuel	=+0.60
5) Crop sale	=-75.60(MH,L); 88.2(M)	5) Seed + Fert.	=+4.87
6)	= -	6)	= -

BARLEY		GRASS	
V.C.	= -	V.C.	= -
1) Seed, fert.	= +5.720	1) Seed	= +1.5
2) Spray	= +0.225	2) Fencing	= +2.0
3) 40% subsidy	= -1.880	3)	= -
4) Drier fuel	= +0.450	4)	= -
5)	= -	5)	= -
6) 60% subsidy	= -2.820	6)	= -

IRRIGATED GRAZING		FEED ROOTS	
V.C.	= -	V.C.	= -
1) Seed, $\frac{1}{2}$ comp. fert.	=+5.01	1)	= -
2) Fencing $\frac{1}{2}$ Nit. F.	= +4.80	2) Seed, Fert.	= +11.06
3) $\frac{1}{2}$ fertiliser	= +5.31	3)	= -
4)	= -	4)	= -
5)	= -	5)	= -
6)	= -	6)	= -

GRAZING

V.C.	=	–
1) Comp. Fert.	=	+4.68
2) Nit. fert.	=	+2.40
3) Comp. fert.	=	+2.34
4)	=	–
5)	=	–
6)	=	–

HAY

V.C.	=	–
1) Comp. fert.	=	+3.51
2) $\frac{1}{3}$ Nit. fert, twine	=	+2.20
3) $\frac{2}{3}$ Nit. fert.	=	+2.40
4)	=	–
5)	=	–
6)	=	–

SILAGE (1 CUT)

V.C.	=	
1) Comp. fert.	=	+4.68
2) $\frac{1}{2}$ Nit. fert.	=	+1.20
3) $\frac{1}{2}$ Nit. fert.	=	+1.20
4)	=	
5)	=	
6)	=	

SILAGE (2 CUTS)

V.C.	=	–
1) Comp. fert.	=	+4.68
2) Nit. fert.	=	+2.40
3) Comp. fert.	=	+2.34
4)	=	
5)	=	
6)	=	

POT. SOLD (AUT.)

V.C.	=	–
1)	=	–
2)	=	–
3)	=	–
4)	=	–
5) 10T Pot.	=	-150.0
6)	=	–

POT. SOLD (SPRING)

V.C. 60% of value	=	+102.0
1) Sell 60%	=	-102.0
2)	=	–
3)	=	–
4)	=	–
5)	=	–
6) Sell 40%	=	-68.0

WHEAT SOLD (AUT.)

V.C.	=	–
1)	=	–
2)	=	–
3)	=	–
4) Sell $\frac{1}{3}$	=	- 73.0
5) Sell $\frac{2}{3}$	=	-147.0
6)	=	–

WHEAT SOLD (SPRING)		BARLEY SOLD (AUT.)		BARLEY SOLD (SPRING)	
V.C. $\frac{2}{3}$ of value	= +180.0	V.C.	= -	V.C. $\frac{2}{3}$ of value	= +147.0
1) Sell $\frac{2}{3}$	= -180.0	1)	= -	1) Sell $\frac{2}{3}$	= -147.0
2)	= -	2)	= -	2)	= -
3)	= -	3)	= -	3)	= -
4)	= -	4) Sell $\frac{2}{3}$	= -127.0	4)	= -
5)	= -	5) Sell $\frac{1}{3}$	= -63.0	5)	= -
6) Sell $\frac{1}{3}$	= -90.0	6)	= -	6) Sell $\frac{1}{3}$	= -73.0

BARLEY BOUGHT (10T)		BARLEY FED (10T)		STRAW USED (10T)	
V.C.	= -	V.C.	= -	V.C.	= -
1) (Spring)	= +230.0	1)	= +1.2	1)	= -
2)	= -	2)	= -	2)	= -
3)	= -	3)	= -	3)	= -
4) (Aut.)	= +200.0	4)	= -	4) Twine	= +5.0
5)	= -	5)	= +0.5	5)	= -
6)	= -	6)	= +0.8	6)	= -

SOYA MEAL		LABOUR
V.C.	= -	One Man = £125 in each period. Overtime £0.3708/hr., Casual Labour £0.325/hr.
1) $^{2}/7$th	= +12.57	1) WDOT, Wet OT, Cas. lab. - 15/2 - 15/4
2)	= -	2) W.D.O.T. - 16/4 - 20/6
3)	= -	3) W.D.O.T., Wet O.T. - 21/6 - 15/8
4) $^{1}/7$th	= +6.29	4) W.D.O.T., Wet O.T. - 16/8 - 18/11
5) $^{2}/7$th	= +12.57	5) $\frac{1}{2}$ WDOT, $\frac{1}{2}$ Wet OT, $\frac{1}{2}$ Casual - 19/11 - 14/2
6) $^{2}/7$th	= +12.57	6) " , " , " - 19/11 - 14/2

TRACTOR + TRAILER	POTATO PLANTER	FORAGE HARV.
V.C. Tr-1035, T-160 = +1095.0	V.C. Cost = +405.0	V.C. Cost = +376.0
1) $^1/_6$ Repr. + Fuel = +38.229	1) Repr. = +Calc	1) = –
2) = +38.229	2) = –	2) $\frac{2}{3}$ Repr. = +Calc.
3) = +38.229	3) = –	3) $\frac{1}{3}$ Repr. = +Calc.
4) = +38.229	4) = –	4) = –
5) = +38.229	5) = –	5) = –
6) Depr. + $^1/_6$ Rep. + Fuel = +206.229	6) Depr. = +Calc.	6) Depr. = +Calc.

BALER	POTATO HARV.	COMBINE
V.C. Cost = +758.0	V.C. Cost = +860.0	V.C. Cost = +2040.0
1) = –	1) = –	1) = –
2) = –	2) = –	2) = –
3) Repr. = +Calc.	3) = –	3) = –
4) = –	4) Repr. = +Calc$\frac{1}{2}$	4) Repr. = +Calc.
5) = –	5) = –	5) = –
6) Depr. = +Calc.	6) Depr. = +Calc.	6) Depr. = +Calc.

BEET HARV.	POTATO DRESSER	F.Y.M. (4 Variables)
V.C. Cost = +470.0	V.C. Cost = +850.0	V.C. = –
1) = –	1) = –	1) Repr. = +2.92 (15/2-16/4)
2) = –	2) = –	2) = –
3) = –	3) = –	3) Repr. = +2.92 (20/6-15/8)
4) = –	4) = –	4) Repr. = +2.92 (16/8-18/11)
5) Repr. = +Calc.	5) $\frac{1}{2}$ Repr. = +Calc.	5) $\frac{1}{2}$ Repr. = +1.46 (19/11-14/2)
6) Depr. = +Calc.	6) $\frac{1}{2}$ Repr, Depr. = +Calc.	6) All deprec.; $\frac{1}{2}$ Repr. = +3.65 (19/11-14/2) or 5.11

SILOS.

V.C. 1000 cf.	= H.Silo +120; T.Silo + 200	
1)	=	-
2)	=	-
3)	=	-
4)	=	-
5)	=	-
6) Deprec.	= H.Silo +10; T.Silo +20	

BARLEY BEEF (STRAW)

V.C. Av.value of stock/space	= +50.0 (+63.0 on slats)
1) $^1/6$ of annual margin	= -9.333
2) "	= -9.333
3) "	= -9.333
4) "	= -9.333
5) "	= -9.333
6) "	= -9.333 (-8.033 on slats)

18 MTH FRIESIANS

V.C. 1 @ 4mth + 1 @ 16mth	= +103.14
1) Sell fat animal	= -77.89
2)	= -
3)	= -
4) Buy calf (+ mort.)	= +15.80
5) Conc., Vet.	= +14.84
6) Subsidy	= -9.75

WINTER CATTLE

V.C. Fat animal less haulage	= +94.0
1) Sell $^3/5$, haulage £0.6	= -56.4
2) Sell $^2/5$, " £0.4	= -37.6
3)	= -
4)	= -
5) Buy/animal + haulage	= +72.5
6) Buy 1; sell 1 less haulage	= -21.5

SUMMER CATTLE

V.C.	= -
1)	= -
2) Buy + haulage	= +73.5
3)	= -
4) Sell, - haulage	= -89.0
5)	= -
6)	= -

EWES (10)

V.C. Av.value of ewes	= +120.0
1) Fencing, Vet.	= +4.500
2) Sell 20% lambs; Lamb Conc.	= -17.250
3) Replacements, Sell wool + 70% lambs	= -46.575
4) Sell 10% lambs + culls	= -16.625
5)	= -
6)	= -

PIGS (10)

V.C.	= –
1)	= –
2) 10 weaners, $\frac{1}{4}$ cone	= +67.000
3) $\frac{1}{2}$ cone, misc., vet.	= +15.552
4) $\frac{1}{4}$ cone, Sale of pigs	= −152.740
5)	= –
6)	= –

DAIRY COWS (BYRE)

V.C. Av.value/cow + housing	= +185.0
1) $^1/6$ of annual margin	= −17.09
2) "	= −17.09
3) "	= −17.09
4) "	= −17.09
5) "	= −17.09
6) "	= −17.09

DAIRY COWS (SF)

V.C. Av.value/cow + housing	= +195.0
1) $^1/6$ of annual margin	= −18.442
2) "	= −18.442
3) "	= −18.442
4) "	= −18.442
5) "	= −18.442
6) "	= −18.442

APPENDIX H.

FEED SUPPLY/CONSUMPTION BALANCES

In the planning model, livestock feed requirements and supplies of feed grown on the farms, and purchased, are balanced by four constraints.

Row 51: The 'Barley Balance' (see Section 13.06) which relates the disposal of barley by various methods, to the supply, includes as means of disposal, specific barley requirements for several types of stock. For barley-beef and pigs, barley is the only feed supply used. Sheep, Friesian beef, and dairy cows require specific amounts of barley in addition to other feed. Barley can also be used as 'Barley Fed', a variable which contributes to the general feed supply.

Row 41: The 'S.E. Balance' ensures that the total calculated requirement of Starch Equivalent for all stock (other than barley-beef and pigs) shall not exceed the total supply from all sources.

Row 42: The 'D.C.P. Balance' similarly relates livestock requirements of Digestible Crude Protein to the supply.

Row 43: The 'D.M. Balance' ensures that the total Dry Matter content of foods fed to stock other than pigs and barley-beef does not exceed the appetite of the stock, which is defined in terms of dry matter intake.

LIVESTOCK REQUIREMENTS

BARLEY BEEF

1 animal sold @ 500 D.W. @ KO% of 57%	=	877.2 lb. L.W.
1 " bought	=	200.0 lb. L.W.
Liveweight gain		677.2 lb.

677.2 lb. @ 5.8:1 conversion requires 35.07 cwt. feed

35.07 cwt. feed @ 85% barley = 1.491 Tons barley per animal fattened

Fattening period = 279 days: 1.308 animals fattened per space per year

Barley per barley beef unit of one space for one year = 1.95 Tons

PIGS: One pig sold fat = 200 lb. L.W.

One store pig bought+ 40 lb. L.W.

Liveweight gain = 160 lb.

160 lb. L.W.G. @ 4·6:1 conversion = 0.328 Tons of feed

0.328 tons @ 80% barley = 0.2624 Tons barley per pig

One unit of 10 pigs fattened requires 2.624 Tons of barley

SUMMER FED CATTLE These are grass fattened, and have no winter feed requirement.

WINTER FED CATTLE The unit is of two cattle fattened in succession from 8 cwt. to 10 cwt. The second animal spends $^{2}/5$ths of its time on the farm on grass. Thus the total weight gain on winter feeds is 1.6x2 cwt. = 358.5 lb. = 2 lb. L.W.G./day over the winter period of 180 days. The average liveweight is taken to be 9 cwt. and from the chart* in Figure S the daily nutrient requirements per animal are estimated as 10.28 lb. S.E. and 1.21 lb. D.C.P. within a daily intake of 20.75 lb. D.M. Thus the matrix coefficients relating to 180 days are:

Row 41 (100 lb. S.E.)	:	18.504
Row 42 (100 lb. D.C.P.)	:	2.178
Row 43 (100 lb. D.M.)	:	-37.35

18 MTH FRIESIAN BEEF Young Friesian calves are bought in October and sold fat at 18 month of age. Feed requirements for the first winter are based on the feeding of calves in trials carried out in 1962 by the North of Scotland College of Agriculture. These are: 70 gallons of milk/milk substitute, 4½ cwt. of purchased concentrates and 4½ cwt. of barley, plus turnips and silage supplying 238.4 lb. S.E. and 34.11 D.C.P., and containing 444.4 lb. D.M.

Nutritional requirements in the second winter assume a liveweight gain of 273 lb (from 655 lb. to 928 lb.) in 180 days = 1.5 lb/day, with an average

* C. Ball, Animal Husbandry Dept., North of Scotland College of Agriculture, Nov. 1960.

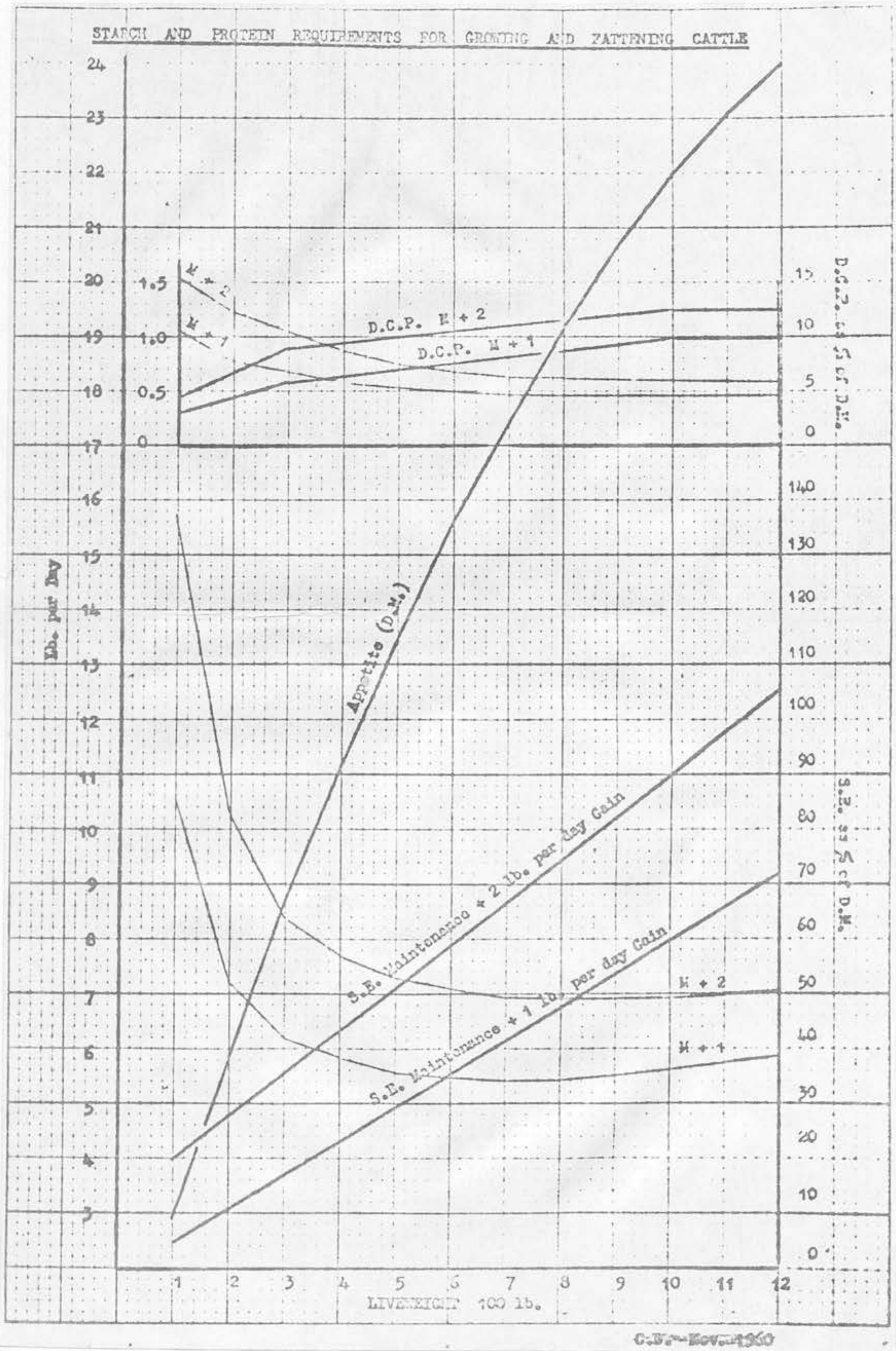


FIGURE S: Energy and Protein requirements and Dry Matter capacity of growing and fattening cattle (C. Ball, N. of Scotland Coll. of Agric.)

weight over the period of 791 lb. From Figure S, the daily requirements are estimated as 8.05 lb. S.E. and 1.10 lb. D.C.P. with an intake of 19.0 lb. D.M. Thus the matrix coefficients for the Friesian Beef enterprise, relating to a 180 day winter for one calf and one 12-18 month old animal, are:

Row 41 (100 lb. S.E.)	:	16.8740
Row 42 (100 lb. D.C.P.)	:	2.3211
Row 43 (100 lb. D.M.)	:	-38.6440*
Row 51 (1 Ton Barley)	:	0.2250

EWES Assuming that ewes have to be hand fed for 15 weeks from 1st January to 15th April, and that feeding has to provide for maintenance plus one gallon of milk per week (pregnancy allowance), then the weekly nutrient intake per ewe,** and the matrix coefficients per 10 ewes for the 105 day period would be:

	S.E.	D.C.P.	D.M.
Maintenance	11.5	0.58	
Pregnancy	4.0	1.00	
Total	15.5	1.58	27.0

Row 41 (100 lb. S.E.)	:	23.25
Row 42 (100 lb. D.C.P.)	:	2.37
Row 43 (100 lb. D.M.)	:	-40.50
Row 51 (1 Ton Barley)	:	0.344

A specific ration of barley is required, rising from 0.75 lb./ewe/day to 2.0 lb./ewe/day over an eight week period, in addition to the above nutrients.

DAIRY COWS (BYRE) Nutrient requirements are based on Friesian cows of 11 cwt. L.W. giving 927 gallons of milk/year (average daily yield 2.54 gallons). An addition of 0.1 gallons/day is made to allow feeding for ½ gallon over current yield during the first 70 days of lactation. Assuming 7.0 lb. S.E. and 0.70 lb. D.C.P. per day for maintenance, with 2.6 lb. S.E. and 0.55 lb. D.C.P. per gallon of milk produced per day, the total daily requirements per cow are 13.86 lb. S.E. and 2.16 lb. D.C.P. Maximum dry matter intake is assumed to be 30.0 lb./cow/day.

* An error was made here, in that the figure - 37.844 was used in the planning model.

** Ashton, W.M. "Elements of Animal Nutrition".

For 90 days from 1st July, barley feeding is required at 4 lb./gallon, for one gallon/cow/day. Thus the matrix coefficients (210 day winter feeding) are:

Row 41 (100 lb. S.E.)	: 29.106
Row 42 (100 lb. D.C.P.)	: 4.536
Row 43 (100 lb. D.M.)	: -63.000
Row 51 (1 Ton Barley)	: 0.161

DAIRY COWS (S.F.) While for Dairy Cows (Byre) any available combination of feeds can be selected which will satisfy the nutrient constraints, Dairy Cows (SF) have silage as a basic winter ration. It is assumed that each cow will eat 9 tons/210 day winter (96 lb./day) of silage with an analysis of 23.0 lb. D.M., 12.0 lb. S.E. and 1.70 lb. D.C.P., per 100 lb. of silage. Total nutrient requirements are the same as for Dairy Cows (Byre), so the nutrients supplied by silage are deducted from these, to give the matrix coefficients:

Row 41 (100 lb. S.E.)	: 4.914
Row 42 (100 lb. D.C.P.)	: 1.109
Row 43 (100 lb. D.M.)	: -16.632
Row 51 (1 ton Barley)	: 0.161

FEED SUPPLIES

The feeds made available in the planning model are listed below, together with the nutrient analysis used, the 'feed unit' (the amount of each feed used when 1.00 unit of the appropriate variable is included in a solution), and the total nutrients, in units of 100 lb., which are available from one feed unit. These last are the matrix coefficients used.

	lbs./100lb Feed				100 lb. nutrient/feed unit		
Feed	S.E.	D.C.P.	D.M.	FEED UNIT	S.E.	D.C.P.	D.M.
Soya meal	65.0	50.0	90.0	1 ton	-14.56	-11.2	20.16
Barley	71.3	7.6	85.0	10 tons	-159.7	-17.02	190.0
Silage	12.0	1.7	23.0	10 tons	-26.9	- 3.808	51.5
Hay	35.0	4.4	85.0	3 tons	-23.52	- 2.957	57.0
Bar. Straw	23.0	0.7	85.0	10 tons	-51.5	- 1.568	190.0
Beet Tops	8.5	1.4	16.0	10 tons	-19.0	- 3.136	35.8
Feed Roots	7.3	1.1	11.5	Various, depending on yield.			
Potatoes	18.7	1.1	24.0	"	"	"	"

The matrix coefficients applying to the various sources of stock feed potatoes and feed roots are calculated below.

		100lb SE	100lb DCP	100lb DM
10T Pot.sold Aut.	: 10.526T grown, 5% brock = 0.526T	-2.204	-0.1296	2.83
" " "	; 12.048T " , 10% " = 1.2048T	-5.048	-0.2968	6.48
E.M.C.Pot.(MH land)	: 11.0T " 5% " = 0.55T	-2.304	-0.1355	2.959
" " (M ")	: 12.0T " 5% " = 0.60T	-2.514	-0.1478	3.228
" " (L ")	: 10.0T " 5% " = 0.50T	-2.095	-0.1232	2.69
Roots (MH land)	: 25 Tons per acre	-40.875	-6.16	64.5
" (M land)	: 22 Tons per acre	-35.97	-5.42	56.67

APPENDIX I

Spring Work Criteria (from Smith, ref. 29)

Medium Land, Spring Cultivations, East Midlands

1. A dry day

In February to mid April, a dry day is one with rainfall $\leq$ .07 inches. On and after April 17th a dry day is one with rainfall $\leq$ .09 inches.

2. The initial start to the season's work

2. (a) The day when work begins shall be dry.

The day when work begins shall be one which the ground is not frozen.

2. (b) When, on and after February 7th a total of 7 dry days has accumulated (independently of the occurence of intervening wet days) work may begin after a sequence of 4 further, consecutive dry days.

3. The termination of work

3. (a) In February to mid-April rainfall $\leq$ .14 inches in one day does not interfere with a run of work. Such days are counted as work days.

On and after April 17th rainfall $\leq$ .19 inches in one day does not interfere with a run of work. Such days are counted as work days.

3. (b) In February to mid-April a run of work is ended by a rainfall $\geq$ .15 inches in one day.

On and after April 17th a run of work is ended by a rainfall $\geq$ .02 inches in one day.

If the rainfall of the day which terminates a run of work is $\geq$ .02 inches, that day not counted a work day.

If the rainfall of the day which terminates a run of work is $\leq$ .19 inches, that day is counted a work day.

4. The recommencement of work

4. (a) The day when work begins again after a wet interlude shall be dry.

4. (b) In February to mid-April a days rainfall of $\leq$ .14 inches does not interfere with a run of work.

With a days rainfall in the range .15 to .29 inches work may begin after 1 dry day.

With a days rainfall in the range .30 to .49 inches work may begin after 2 dry days.

With a days rainfall in the range .50 inches work may begin after 3 dry days.

On and after April 17th a days rainfall of $\leq$ .19 inches does not interefere with a run of work.

In this period

With a days rainfall in the range .02 to .29 inches work may begin after 1 dry day.

With a days rainfall in the range $\geq$ .30 inches work may begin after 2 dry days.

4. (c) The dry days specified in section 4 (b) before work can begin again need not be consecutive. If after the termination of work subsequent days are wet, then the interval during which no work is possible is, of course, extended. In such a wet interlude, each successive day is taken as the starting point for the recalculation of the number of dry days required (according to the stipulations of section 4 (b) before work can begin again. Since such counts may in fact overlap, the day adopted for the recommencement of work is that furthest in time from the day when rainfall stopped work.

4. (d) If the wet interlude (when no work is possible according to the criteria above) extends over a period of 5 or more consecutive days, then the following requirements must be met before work can begin again.

In February to mid-April, 3 consecutive dry days must occur before work can recommence.

FARM WORK PLANNING AND THE ADJUSTMENT OF LABOUR AVAILABILITY TO ALLOW FOR WEATHER LOSS

This article gives a brief summary of labour planning methods which have been used, commenting on their usefulness where detailed planning is concerned. The lack of information on loss of working time due to bad weather is noted, and the main part of the article is devoted to a description of the assessment of this loss using farm overtime records and two meteorological records- daily rainfall and 'State of Ground'. This is not claimed to be a sophisticated approach, but rather, a simple attempt to bridge a gap encountered in the course of other work. Thanks are due to Mr. J. Harkins for reading and commenting on earlier drafts. Any inconsistencies and errors are the author's responsibility.

In arable farming, the labour-machinery complex is responsible for 40-60 per cent of total costs. It is, therefore, an area in which effective planning of use of resources can be expected to improve the farm income. It should be noted that labour saving is too restricted a concept of labour planning, since the objective-to increase farm income-can be attained not only by the re-organisation of work to reduce labour and machinery costs, but also by the re-organisation of existing staff and equipment to increase output. However, only when the existing utilisation of labour and equipment can be depicted realistically, is it possible to predict accurately the likely effect of a change in organisation or in technique.

To be effective, the method of planning used must show clearly why labour requirement peaks arise, and also the periods during which labour is not productively employed.

This article indicates some methods of labour planning which have been used, points out some of the difficulties which arise in trying to attain the aim of realistic depiction of labour utilisation, and describes an approach to part of the problem which has been found to be effective by the author.

A simple planning method uses the concept of man-days per year. From surveys, an assessment is made of the number of man-days required per acre, per year, for the various crops. The total number of man-days per year for the farm under consideration is calculated from these figures, and the size of staff required is estimated by dividing this total requirement by the number of man-days available per man per year. The supply per man is given by Sturrock (1) as 250 days which makes some allowance for time spent on 'unproductive' work, such as hedging, ditching, etc., and for time lost due to bad weather. Alternatively, availability is given as 280-300 days per man by Watson & More (2), and in this case, 15 per cent is added to the requirement to allow for 'unproductive' work. Hayes (3) expresses requirements for and availability of labour in man-hours per year.

This method of labour planning fails to consider a vital factor - the seasonality of labour peaks. With potatoes, for example, 20-35 per cent of the annual demand for regular labour is within the lifting period. Hayes, and also Blagburn (4), approach this difficulty by using histograms of the average monthly labour requirement for each of the various enterprises, to estimate which combination of enterprises is likely to give a reasonably even work load throughout the year.

An improvement of this, mentioned in several sources, is to divide the year into periods and to calculate the labour requirement in man-hours, etc., for each period. The periods used may be months, or half months, or periods which coincide with the cropping seasons, e.g. mid-Feburary to mid-April, as the period within which all spring sowing must be accomplished.

In using any period shorter than a season, it may be necessary to divide the labour requirement for one operation between two or more periods. Harvest labour requirements, for example, may have to be divided between the two one month periods of August and September. The proportion of requirements thus allotted to each period, if based on the average situation, may well be unrealistic. In the individual case, the period over which a job is spread depends upon the date on which it can be started, which may depend on the finishing date of the previous job, and on how 'big' the job is, in relation to the available resources of labour and machinery.

If a period of time equivalent to a farming season is used, it is not necessary to divide labour requirements, but there is again a difficulty. A season is here regarded as the period between the earliest start (E.S.) date, and the latest finish (L.F.) date, for a series of similar operations. Within this season, however, there may well be E.S. and L.F. dates associated with particular crops. For example, spring cultivations and sowing may be possible between 20th February and 15th April, but it may be deemed essential to finish sowing early potatoes by 20th March.

The use of any period of less than one year does, however, bring attention to the fact that the size of farm staff is normally governed by the number of experienced men required in the busiest season. These men must normally be employed for the whole year. This was recognised many years ago by J. C. Morton (5), who, writing in 1887, gave tables of the monthly 'man+horse-pair' days required for the operation of a 240 acre arable farm. Labour needs in October were the greatest of the year, being 80 days, and Morton says-'. . . . and as only 22 or 23 days fit for field work can be expected in that month, $3\frac{1}{2}$ teams must be provided . . . . ; and these must be maintained and paid throughout the year, notwithstanding that it is only during a few months that they are all needed'.

It is difficult to give a true representation of a farm labour profile using any of the methods just described. There are two reasons:

(1) The farm labour situation is of a dynamic nature and cannot be adequately described within fixed parameters, the start of an operation often depending, as already mentioned, on the completion of an earlier one.

(2) An operation which in fact requires 5 men to work for 3 hours, and is thus represented as 15 man-hours, can be interpreted as 1 man working for 15 hours (or 2 men for $7\frac{1}{2}$ hours, etc.).

Thus a continuous time scale, and recognition of the size of squad required to handle an operation, are required. The method used by Wallace and Burr (6) and further illustrated by Kerr (7), satisfies these requirements. A chart is used on which the horizontal axis represents the passage of time, with allowance made for loss due to bad weather, etc., and the vertical axis represents the number of men required. The continuous time scale is approximated by dividing the year into periods of a month or less, calculating the time available in each period after allowance for weather, etc. and making the assumption that this series of blocks of time represents a continuous time scale. Obviously, the shorter the periods used, the less erroneous this assumption will be.

This method would appear to be capable of giving a fairly true representation of the labour profile, if the data used are accurate. A lack of reliable labour requirement data and of information on the loss of time due to weather is mentioned by MacHardy (8), and Sitterley and Bere (9), and although several publications state that allowance is made for loss of time due to bad weather when calculating available time, they may not describe how the allowance is calculated.

In the course of a study of inter-farm co-operation being carried out by the Edinburgh University Department of Agriculture, it was necessary to forecast farm labour requirements accurately. This necessitated the use of a technique which would reproduce present requirements correctly. The squad labour chart was evidently most suited to this, but available labour requirements data and information on the effect of weather, etc., on the labour supply, were considered to be inadequate.

Farmers assisting in the study were interviewed to discover the rates of work individually attained for the various field operations. The fact that there was a very wide variation in the squad hours per acre required for apparently identical operations, justified mistrust of 'standard' data for use in situations where individual data are obtainable. Information on rates of work was obtained in the form of acres handled in a day of $8\frac{1}{2}$ hours by a given squad, and was reduced to hours per acre, using that squad size.

As previously mentioned, sources of information on the amount of time available per man at different times of year are scarce and tend to be uninformative. Belshaw and Scott (10) note that '. . . . the need to have some reserve for sickness, adverse weather conditions, etc., must be borne in mind'. Estimates of available time by Wallace and Burr'. . . . make allowance for holidays, normal sickness, bad weather, etc., balanced by reasonable overtime'. McFarquhar (11) states that, 'Every allowance has been made in the original data for the effect of bad weather, illness, etc., in the hours available for work'.

The amount of time lost due to holidays is easily found, and the effects of normal sickness may not be very great. Davies (12) found only about 1 per cent of an employed man's time to be lost by sickness.

The time loss due to weather, however, can be considerable, and is difficult to assess. Numerous interacting factors are involved - rainfall, humidity, windspeed, cloud cover, frost, etc., the duration of these, and also soil type and drainage. In addition, it may well be possible to undertake, say, potato lifting, in weather which renders grain harvesting impossible. Sitterley and Bere, have taken into account the combined effect of several climatic factors in assessing the days available for a range of crop operations, and state that due to lack of empirical data on the effect of these aspects of climate, several assumptions had to be made. Unfortunately, no mention is made of what levels of these climatic factors were assumed to be significant, beyond mention of an analysis of weather data to determine the number of days with rainfall $\geq$ 0.01". MacHardy, noting the lack of agricultural meteorological data relating common weather parameters to farming operations, estimates, from data published in the 'Climatological Atlas of the British Isles', that one day's rainfall in excess of 0.4" would stop field work for two days and also considered that the presence of fog would stop harvesting. Tracey (13) estimates 6 weeks of the year to be lost owing to bad weather, and this loss is apparently spread evenly throughout the year.

In the Edinburgh study mentioned, the possible effects of the climatological complex noted earlier were recognised and given consideration. Combine operator's time sheets were examined in relation to appropriate meteorological records. However, the number of assumptions necessary, and the complexity of interaction between the various factors, even in a case such as this, of one crop, in one season, rendered any conclusions of little value.

The possibility of relating soil water balances to land work was also considered, but the fact that soil types can vary widely over a farm, and even within the limits of one field, and the lack of information on the effect of moisture content on the workability of soil made this of little use as a method of estimating loss of time due to weather.

It was therefore decided to examine the relationship between time loss, and such meteorological data as could most easily be handled. Daily rainfall, and the condition of the ground - which would combine the effects of several of the factors mentioned earlier - were the two factors thought to have the greatest direct effect on time loss.

It was thought that if calculated labour requirements for a particular farm were matched with recorded overtime, it might be possible to deduce the appropriate weather constraint on time availability within normal hours.

Records of the number of overtime hours worked by each man, in 2-week periods over a number of years, were obtained from one of the farms in the study. Each year was divided into five seasons to allow consideration of the effects of weather in each season, dates for the start and finish of each 'season' being fixed from farm records.

TABLE A

SEASON	EXTENT	MAIN OPERATIONS
Spring	Mid February-Mid April	Cultivate and plant crops
Early Summer	Mid April-Mid June	Potato cultivations and beet singling.
Summer	Mid June-Mid August	Lift early, and part of second early, potato crop.
Harvest	Mid August-Mid October	Lift rest of second early potatoes. Grain Harvest.
Winter	Mid October-Mid February	Lift main crop potatoes and sugar beet; plough; dress potatoes.

A squad labour chart for each season was constructed, giving the total number of hours (not 'man-hours') required to complete all operations. The number of man-hours of recorded overtime worked in each season was calculated and deducted from the work shown on the chart as in Figure 1, on the assumption that overtime would become necessary as the season's L.F. date approached. This left, for each season, the number of non-overtime hours which could apparently be worked in the season before overtime became necessary.

It may be useful at this point to list the terms used whose meaning may not be self-evident.

FIGURE 1

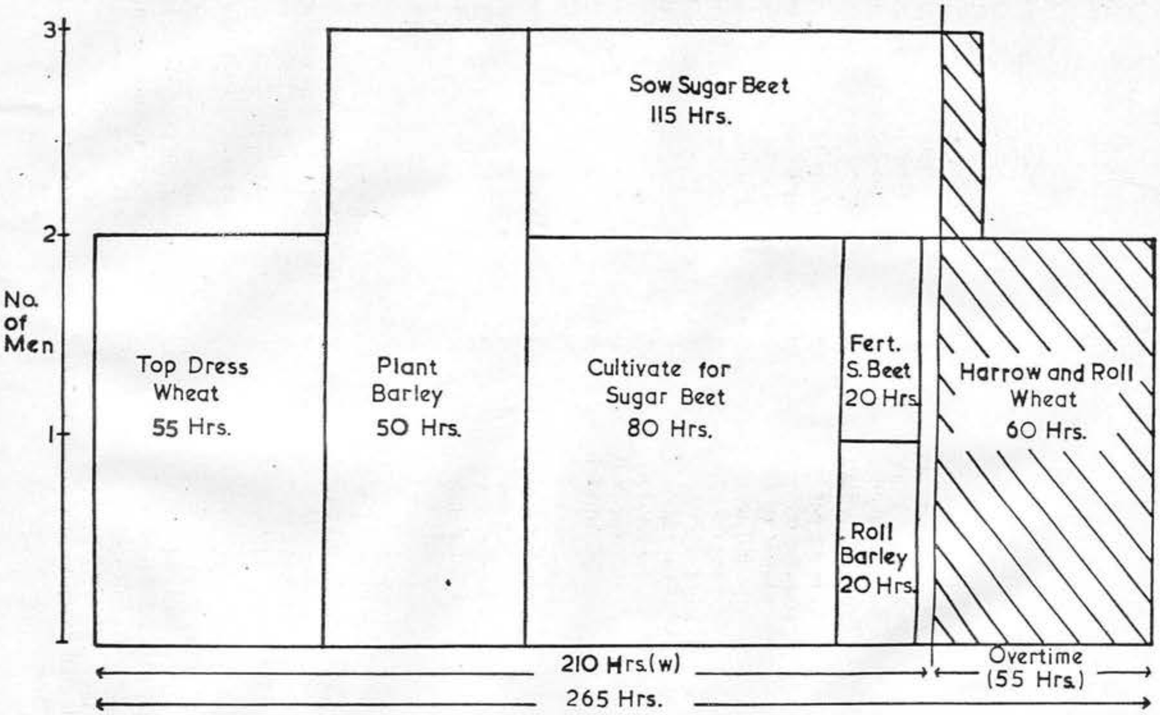


Figure 1 is a simplified representation of the work done in 'Spring' on the farm studied. Top dressing of wheat for example, occupies two men for 55 hours, and barley planting takes three men 50 hours.

FIGURE 2

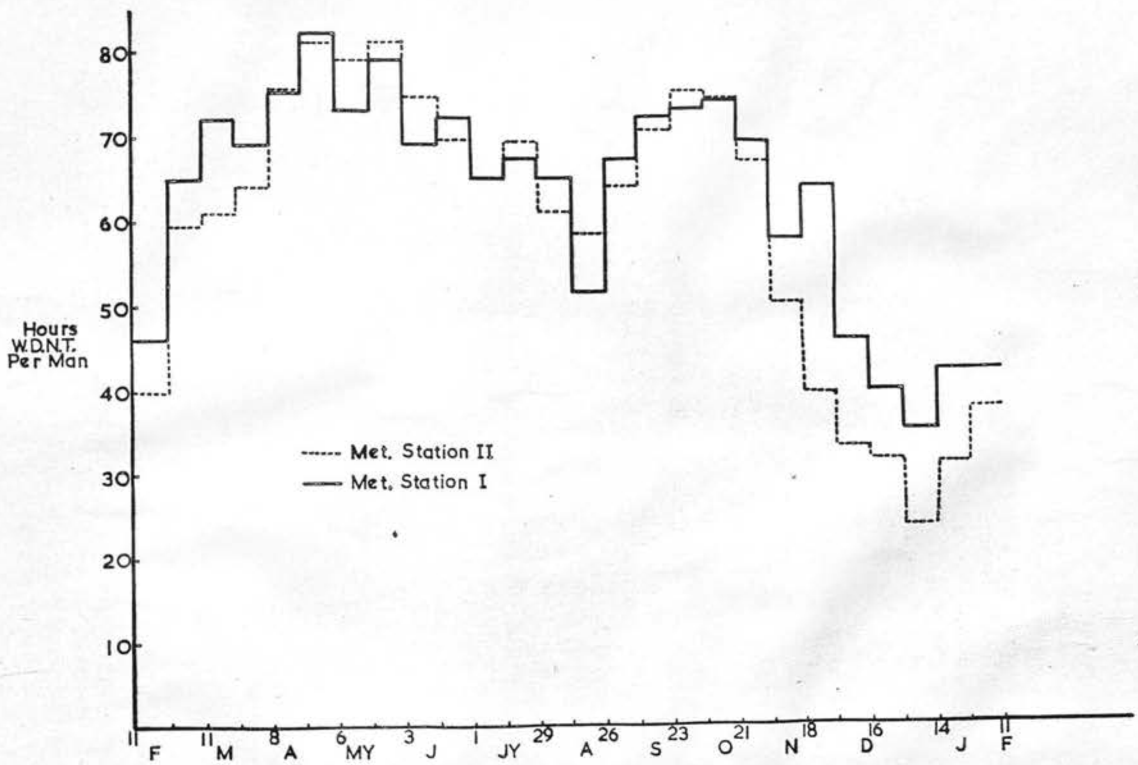


TABLE B

T.N.T. - Total Normal Time - Those hours which are the statutory maximum for tractormen.

W.D.N.T. - Weather Dependent Normal Time - T.N.T. reduced by a factor making allowance for bad weather and sickness.

T.O.T. - Total Overtime - The number of daylight hours left after deducting T.N.T. and an allowance for meals.

W.D.O.T. - Weather Dependent Overtime - T.O.T. reduced by a weather allowance factor.

Non-W.D. Time - Total Time minus W.D. Time. This is not available for the majority of field operations, but may be used for indoor work.

The number of T.N.T. hours available per man in each season was calculated from the Agricultural Wages Board (Scotland) Wages Order. Statutory single day holidays were taken into account here.

The difference between the T.N.T. hours in each season, and the hours apparently worked before overtime became necessary in each season, was expressed as a percentage of the T.N.T. hours available. The equivalent percentage of the number of days in each season was then calculated, and this was taken as the number of days lost due to bad weather.

$$\text{i.e.} \quad D = \frac{d(n - w)}{n}$$

Where D = number of days lost
d = total days in season
n = T.N.T. hours in season
w = hours worked before overtime becomes necessary. (See Fig. 1).

The meteorological records of rainfall and ground condition were then examined. In meteorological records the 'State of Ground' is a subjective estimate, and is based on one plot of ground, but in this case was the only daily record of ground condition available. Ten gradings are recorded:

0. Dry (no appreciable dust or loose sand).

1. Moist.

2. Wet (pools of water present).

3. Surface of ground frozen.

4. Glaze on ground, but no snow or melting snow.

5. Ice, snow, or melting snow covering less than one half of ground.

6. Ice, snow, or melting snow covering more than one half of ground (but not completely).

7. Ice, snow, or melting snow covering the ground completely.

8. Loose, dry snow, dust or sand covering more than one half of ground (but not completely).

9. Loose, dry snow, dust or sand covering the ground completely.

With reference to this scale it was decided that any day with the 'State of Ground' estimated as ≥ 2 should be discounted for field work, and the daily rainfall records were examined to find the precipitation which, in combination with 'State of Ground' ≥ 2, would make the number of days affected in each season similar to the number of days (D) calculated as being lost in each season. The daily rainfalls fitting this requirement ranged from (16 per cent of dry days + Rainfall $\geq$ trace ($0 <$ trace $< 0.01"$)), to (Rainfall $\geq 0.04"$). This was thought to be unrealistic, since even 0.04" per day is light rain, unless it falls over a very short time.

Attention was then turned to the labour requirement data. These were derived by interview, not from time studies, and rates of work quoted might tend to be those which would be attainable on a good day, with no breakdowns, etc. Also there is much necessary work which arises because of operations, but for which it is very difficult to make specific allowance. Travelling time, getting out and testing machinery, clearing up after operations, supervision of work by a member of the working team, are in this category. This may be termed

'Complementary Time' (C.T.). Labour requirements were increased by 25 per cent to make allowance for this factor, 'D' was recalculated, and the daily rainfall levels fitting 'D' were re-assessed. The majority of these were in the range (Rainfall $\geqq$ 0.08") to (Rainfall $\geqq$ 0.12"), and (Rainfall $\geqq$ 0.1") was taken as the effective level. The W.D.N.T. hours for each of the seasons were calculated according to the weather constraint (State of Ground $\geqq$ 2 or Rainfall $\geqq$ 0.1") and apparent O.T. requirements produced. These were less than the recorded amounts of O.T. in Spring, Early Summer and Harvest, rather more than the true amounts in Winter and on either side of the true amounts for the Summer periods.

This was considered to be satisfactory, since not all overtime is due to work being behind schedule. At harvest a large amount of overtime is often worked from the start in case of a break in the weather; sugar beet singling in Early Summer is usually completed as quickly as possible. The overprediction of winter overtime may be due to the fact that the two main occupations, after all crops are lifted, are ploughing and potato dressing. Ploughing requires less Complementary Time allowance than most operations; and potato dressing, with shed storage, may be done largely in weather unsuitable for field operations.

The T.N.T. hours per man in 14 day periods throughout the year were calculated from the current Agricultural Wages Board (Scotland) Wages Order, and reduced to W.D.N.T. hours according to the percentage of days in each period with (State of Ground $\geqq$ 2 or Rainfall $\geqq$ 0.1"). This was repeated using data from a second Meteorological Station, as several of the farms in the study were likely to be affected by weather similar to that experienced at Meteorological Station 11. <u>Figure 2</u> shows the amounts of W.D.N.T. calculated as being available under the weather conditions found at each Meteorological Station. Station I is on the coast, while Station II is a few miles inland, with high ground between it and the coast.

Total overtime per 14 day period was calculated as indicated in Table B, and was reduced to allow for weather loss giving the W.D.O.T. available per period. Overtime is treated as a separate resource and is not included as part of the total time available, as has been done by some authors (6, 13).

Squad labour charts for a complete year were then drawn up for each of the farms involved in the study, using overtime where necessary, and allowing the use of non-W.D. time for operations which are independent of soil conditions and weather. The farmers concerned examined these charts and agreed that they were accurate representations of the labour situations and problems encountered on each farm. Also, the numbers of men calculated as necessary, using data derived from present techniques, were the numbers of men actually employed.

Labour planning of this type has wider application than simply to forecast staff size. It can be used to identify accurately the operation(s) which make this staff necessary, and as Morton observes 'It is, as we have already pointed out, in the power of steam cultivation to reduce the demands made by the Autumn cultivation and Spring ploughing on the horsepower of the farm; and, by its assistance at these two periods to reduce the number of horses required throughout the year'. It should also be possible, as medium term weather forecasting improves (14), to use this type of technique to plan work in detail for two to three weeks ahead.

The author agrees with MacHardy, and with Sitterley and Bere, that before any real progress is made in farm labour planning, standard techniques for gathering and expressing labour requirement data need to be developed, and a specific study of the climatological constraint on workable time is required. The latter might be under taken by the type of research organisation advocated by Professor Duckham (15).

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VARIATIONS IN THE MARGINAL VALUE OF AGRICULTURAL LABOUR DUE TO WEATHER FACTORS

W. J. TAGGART

The intention in this paper is to describe an attempt to isolate the effect that variations in the weather might have on farm profit, by affecting the availability of labour. It should be borne in mind that the implications of the results obtained will depend almost wholly on the accuracy with which the loss of time due to bad weather can be calculated. The number of hours suitable for outside work on an arable farm were calculated for three "weather situations", using the records of three rainfall recording stations near Edinburgh, and applying the criteria suggested by Taggart (1967). These three sets of workable time were then used successively to arrive, by linear programming, at three optimal plans for a single farm, the labour availability being the only variable parameter.

THE FARM

The farm used for the comparison is one of 403 acres, made up of 183 acres of medium land (Dreghorn soil series) and 220 acres of light land (Frazerburgh and Macmerry soil series). The possible crops, and their yields, are given in Fig. 18. A full-time staff of five men is employed, plus casual labour required for potato dressing in winter. Several livestock enterprises are possible, but no stockmen are employed, the work on stock being done by the general staff. The livestock enterprises considered are: winter fattened cattle; summer fattened cattle; 18 month beef; breeding sheep with lambs fattened; pigs fattened in cattle courts in summer.

CROPS	MEDIUM LAND YIELD	LIGHT LAND YIELD
	TONS/ACRE	TONS/ACRE
First early potatoes	7	7
Second early potatoes	9	9
Early maincrop potatoes	12	10
Maincrop potatoes	12	10
Sugar beet	14	12
Wheat	2	1.6
Barley	1.85	1.5
Grazing		
Silage (1 cut)	8.4	7.5
Hay	2.8	2.5

Fig. 18. Crops considered for inclusion in the farm plans.

The linear programming model used includes: capital supply at 9 per cent interest; limitationsimposed by a disease control rotation and by available crop storage and livestock accommodation; least-cost feed selection for livestock; various crop disposal alternatives; optional use of overtime and casual labour. Machinery selection was not included, in order to save computer time.

THE RAINFALL STATIONS

The records of three stations were used to provide the variations in weather. It should be noted that all three are within a relatively small area and that the pattern of farming does not vary markedly, between actual farms in the three districts. Station 1 is at 605 ft. above sea-level, 6 miles south of Edinburgh. Station III is about 50 ft. above sea-level, on the coast 23 miles north-east of Station I. A ridge of high ground rises to about 350 ft. between the sea and Station II, which is 150 ft. above sea-level, 7 miles south-wouth-west of Station III, and 16 miles east of Edinburgh.

For each 14-day period through the year, the number of days reckoned to be suitable for outside work on an arable farm is expressed as a percentage, using data from the three stations. These weather-dependent percentages (W.D.%) are compared in Fig. 19. The total time in any period, less the weather-dependent time, is assumed to be "wet", i.e. unsuitable for most outdoor work on an arable farm. It will be seen that the main differences in the weather-dependent percentage are in December, January, February and March.

From this point, for convenience, the names Station I, Station II and Station III will be used to denote the three "farms".

In the model, the year has been divided into five seasons: spring, February 15th - April 15th; early summer, April 16th - June 20th; summer, June 21st - August 15th; harvest, August 16th - November 18th; winter, November 19th - February 14th. The average weather-dependent percentages for these seasons are shown, and inter-station variations compared, in Fig. 20 which possibly shows more clearly than Fig. 19 that the variations are mainly in winter and spring, In spring, Station I has 83 per cent of the workable time available at Station II, and in winter 61 per cent. During the harvest seasons the three Stations are very similar, Station I having 96 per cent of the workable time available at Station III.

As stated earlier, the farm staff is five men, and so limits are set on the total number of hours available in each season. The time available in each season is subdivided into "weather-dependent" and "wet" according to the

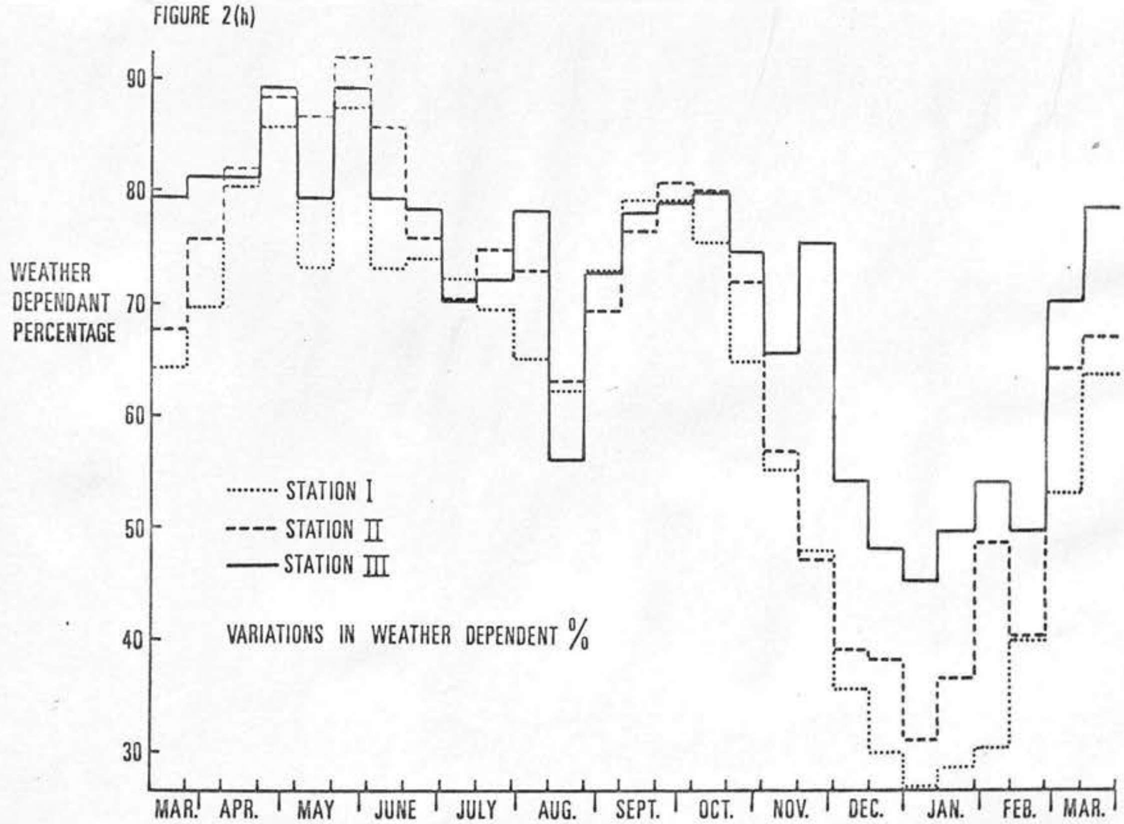

FIGURE 19 Comparison of proportions of time suitable for outdoor work (periods of two weeks).

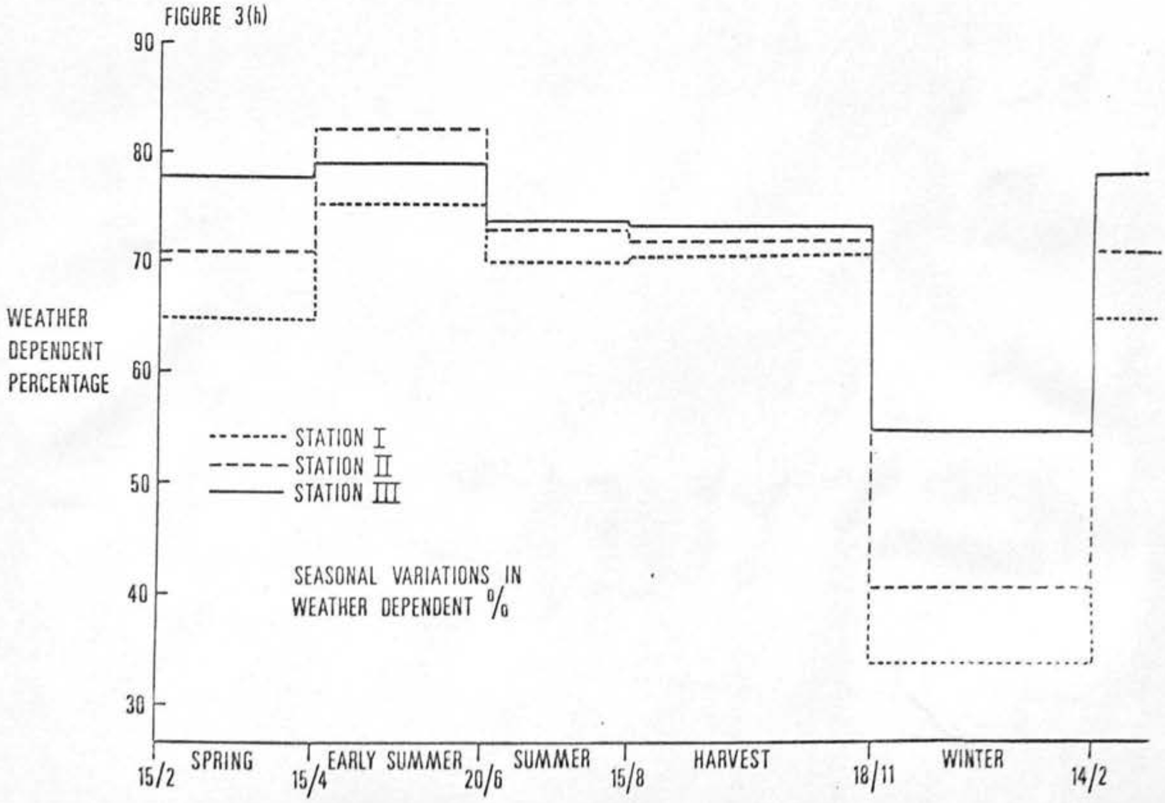

FIGURE 20 Comparison of proportions of time suitable for outdoor work (seasonal periods).

appropriate W.D.%. Weather-dependent time can be used for "wet" weather work, if necessary (but not vice-versa), and overtime labour is available at the appropriate cost, if required.

The cropping in the optimal solutions for the three stations is compared in Fig. 21. It should be remembered that the variations in cropping balance are due solely to changes in the balance of labour availability, and not to any alteration in labour requirement or crop yield, although these will also be affected by the weather.

The profit from the farms varied in response to the effect of the three local climates on labour availability by increasing by £492 or £1.22 per acre from Station I to Station II, and by £810 or £2.01 per acre from Station II to Station III.

One of the most useful attributes of linear programming as a planning tool is the amount of peripheral information which is available. In this case the value of additional weather-dependent labour is of interest. The scarcity value of one man-hour varies with the season, being nil in the early summer period, from April 16th to June 20th when the staff is underemployed, £0.98 to £1.02 in the summer period, June 21st to August 15th, when early potato lifting is under way, and £1.95 to £2.00 in the winter period. Now these indications are useful, showing the breakeven value of labour, per hour, for weather-dependent work in these seasons, but in this form could relate only to the hiring of casual labour. However, if a full-time man is to be hired, then he has to be paid when his labour is worth nothing, as well as when his labour is worth £2 per hour. Therefore the annual break-even value of an additional man is calculated as demonstrated by Tyler (1966). For Station I, this is £1288; for Station II, £1355; and for Station III, £1516.

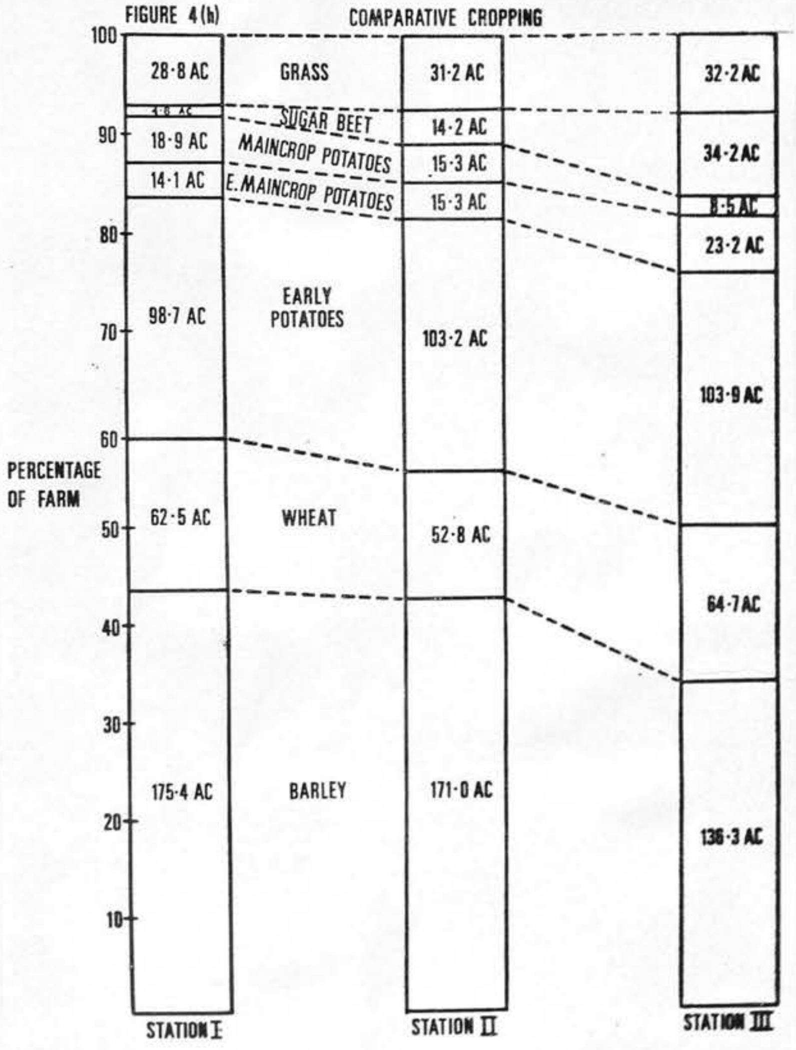

FIGURE 21. Effect of labour availability variations on crop distribution selected.

CONCLUSION

This paper is not intended to define the economic effect of the weather on farm profitability via labour availability, since it is not possible to generalize on this topic. However, subject to the assumption that it is possible to assess the effect of weather on labour availability, a possible method of measuring the economic effect of weather variations is suggested. The amount of profit variation found would seem significant, even in response to climate differences which, to a non-meteorologist, seem slight.

The results of the comparison are summarized in Fig. 22.

STATION	STATION I	STATION II	STATION III
Weather	Poorest	Intermediate	Best
% roots	33.8	36.7	42.1
% cereals	59.1	55.5	49.9
% grass	7.1	7.8	8.0
% of farm Gross Margin coming from livestock	19.2	19.4	19.7
Profit per acre increase over Station I	£0	£1.22	£3.23
Break-even annual value of an extra man	£1288	£1355	£1516

FIGURE 22. Comparative summary of enterprise distribution, profitability, and the marginal value of labour.

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APPENDIX L

CALCULATION OF AVAILABLE WORK HOURS PER MAN

This calculation divides the available time per man into four categories - Weather Dependant Normal Time (W.D.N.T.); Weather Dependant Overtime (W.D.O.T.); Wet Normal Time (Wet N.T.); Wet Overtime (Wet O.T.). The separation of 'Weather Dependant' from 'Wet' time is based on the assumption that all days on which 0.1" or more of rainfall or on which the 'State of Ground' estimation by the meteorological recorder is "Wet (pools of water present)" (Grade 2), or worse, are unsuitable for most outdoor work and soil cultivations. The derivation of these criteria is described in Appendix J.

The year was divided into periods of 14 days each, starting at 1st January (with 15 days from 17/12 - 31/12 and an average of 14¼ from 25/2 - 11/3). The number of days on which the stated criteria were exceeded were counted for each 14 day period in each year from 9/4/1956 to 8/4/1964, using the records from the two recording stations nearest to the farms.

(This was the only period over which both records were available). From this, the 'W.D.%' for each 14 day period was calculated, as shown in Table 43.

F1 and F4 computations use the North Berwick W.D.%, the other four farms use the Haddington W.D.%, and The Farm uses an approximation of (2 x Haddington + 1 x N. Berwick) /3.

Figure T shows the times of dawn, daylight, sunset and darkness throughout the year (with British Summer Time adjustments).

From this the total available hours per man are estimated for each period, and these are divided as shown in Table 44.

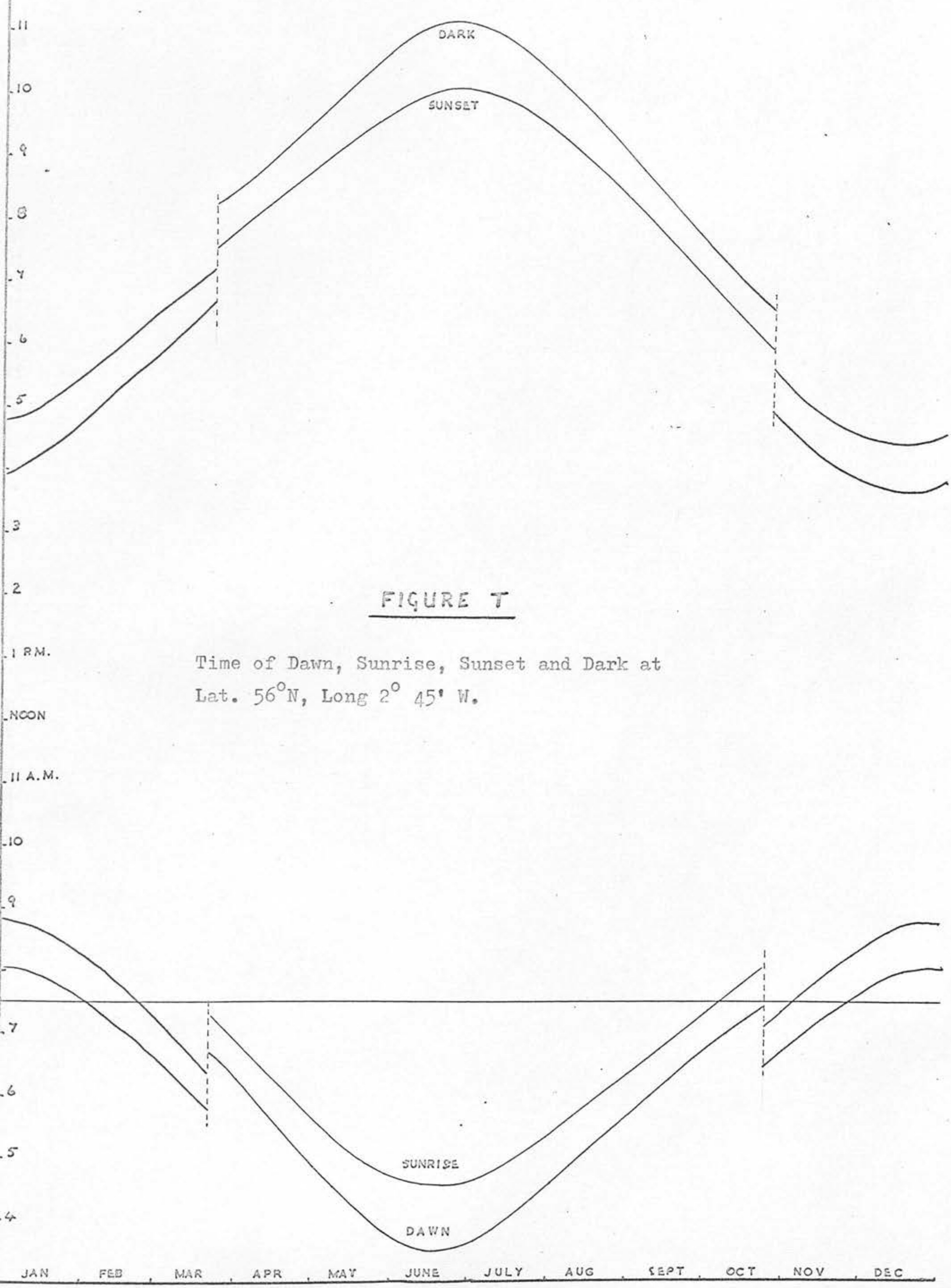

FIGURE T

Time of Dawn, Sunrise, Sunset and Dark at
Lat. 56°N, Long 2° 45' W.

HADDINGTON

	9/4 -22/4	23/4 - 6/5	7/5 -20/5	21/5 - 3/6	4/6 -17/6	18/6 - 1/7	2/7 -15/7	16/7 -29/7	30/7 -12/8	13/8 -26/8	27/8 - 9/9	10/9 -23/9	24/9 - 7/10	8/10-21/10	22/10- 4/11	5/11-18/11	19/11- 2/12	3/12-16/12	17/12-31/12	1/1 -14/1	15/1 -28/1	29/1 -11/2	12/2 -25/2	26/2 -11/3	12/3 -25/3	26/3 - 8/4
1956-57	4	-	1	-	3	4	6	5	6	8	6	3	2	3	4	2	6	4	7	4	9	7	13	1	5	4
1957-58	1	1	4	-	2	3	5	5	2	5	2	6	-	2	3	6	2	9	3	10	8	7	8	7	8	8
1958-59	1	2	3	5	4	6	3	8	2	8	5	4	1	1	1	5	7	10	8	13	13	9	3	-	1	-
1959-60	1	4	-	1	2	6	2	2	-	1	1	3	1	3	3	10	7	9	9	12	10	7	14	6	5	3
1960-61	-	-	2	-	2	-	5	3	6	8	6	4	5	7	8	5	9	11	10	10	4	8	1	4	-	4
1961-62	5	5	-	1	-	-	6	1	4	1	4	2	4	4	5	4	9	11	12	9	6	1	3	10	6	6
1962-63	4	1	2	1	1	-	1	4	4	5	6	3	2	-	3	7	9	9	15	14	14	14	14	10	4	2
1963-64	4	-	3	1	2	8	5	-	6	5	4	1	6	2	4	9	10	5	10	5	7	4	7	2	7	-
8 Yr. Total	20	13	15	9	16	27	33	28	30	41	34	26	21	22	31	48	59	68	74	77	71	57	63	40	36	27
% of period.	17.8	11.6	13.4	8.0	14.3	24.1	29.5	25.0	26.8	36.7	30.4	23.2	18.8	19.6	27.7	42.9	52.7	60.7	61.7	68.9	63.3	51.0	56.2	35.1	32.2	24.1
W.D.%	82.2	88.4	86.6	92.0	85.7	75.9	70.5	75.0	73.2	63.3	69.6	76.8	81.12	80.4	72.3	57.1	47.3	39.3	38.3	31.1	36.7	49.0	43.8	64.9	67.8	75.9

NORTH BERWICK

	9/4 -22/4	23/4 - 6/5	7/5 -20/5	21/5 - 3/6	4/6 -17/6	18/6 - 1/7	2/7 -15/7	16/7 -29/7	30/7 -12/8	13/8 -26/8	27/8 - 9/9	10/9 -23/9	24/9 - 7/10	8/10-21/10	22/10- 4/11	5/11-18/11	19/11- 2/12	3/12-16/12	17/12-31/12	1/1 -14/1	15/1 -28/1	29/1 -11/2	12/2 -25/2	26/2 -11/3	12/3 -25/3	26/3 - 8/4
1956-57	2	2	2	2	7	5	7	5	6	10	5	5	6	3	2	3	1	4	8	5	9	7	9	5	5	4
1957-58	2	1	9	-	1	3	8	7	3	8	4	4	-	2	3	1	1	8	3	9	8	7	8	6	6	8
1958-59	2	2	3	5	2	5	2	7	1	8	5	5	4	-	3	3	1	8	7	12	10	8	1	-	2	1
1959-60	2	2	1	1	2	4	2	2	-	2	-	2	-	2	2	8	4	6	5	4	5	5	14	5	1	-
1960-61	3	-	3	-	3	-	2	2	2	8	4	3	3	6	9	3	6	8	8	8	4	7	1	1	-	3
1961-62	2	4	-	2	4	-	5	1	5	1	3	1	3	6	4	2	7	11	10	7	1	1	-	6	1	4
1962-63	3	-	2	1	1	1	2	6	1	5	6	3	3	1	1	6	1	4	11	14	14	14	14	10	3	1
1963-64	5	1	3	1	3	6	5	1	6	7	3	1	4	2	4	12	6	2	10	2	5	2	9	-	5	-
8 yr. Total	21	12	23	12	23	24	33	31	24	49	30	24	13	22	28	38	27	51	62	61	56	51	56	33	23	21
% of period	18.8	10.7	20.5	10.7	20.5	21.5	29.5	27.7	21.5	43.8	26.8	21.5	20.5	19.6	25.0	34.0	24.1	45.5	51.7	54.5	50.0	45.5	50.0	29.0	20.5	18.8
W.D. %	81.2	89.3	79.5	89.3	79.5	78.5	70.5	72.3	78.5	56.2	73.2	78.5	79.5	80.4	75.0	66.0	75.9	54.5	48.3	45.5	50.0	54.5	50.0	71.0	79.5	81.2

TABLE 43: COUNT OF DAYS WHEN STATE OF GROUND IS 2 OR MORE + OTHER DAYS WHEN RAINFALL IS 0.1" OR MORE

APP. L.

DATE	START	AV. STOP HRS. P.M.	HRS. LIGHT PER DAY	HRS./14 DAYS	MEALS	TOT. AVAIL. HRS.	TOT. N.T. HRS.	TOT. O.T. HRS.	W.D. %	W.D. TOT. HRS.	W.D. N.T. HRS.	W.D. O.T. HRS
9/4 -22/4	7.30 a.m.	8.50	13.33	186.6	28	158.6	90	68.6	81.83	129.5	73.5	56.0
23/4 - 6/5	"	9.20	13.833	193.7	28	165.7	90	75.7	88.69	146.8	79.8	67.0
7/5 -20/5	"	9.50	14.33	200.6	28	172.6	90	82.6	84.23	145.4	75.9	69.5
21/5 - 3/6	"	10.20	14.833	207.7	28	179.7	86.5	93.2	91.07	163.7	78.8	84.9
4/6 -17/6	"	10.45	15.25	213.5	28	185.5	85.3	100.2	83.65	154.8	71.2	83.6
18/6 - 1/7	"	10.50	15.33	214.6	28	186.6	90	96.6	76.76	143.0	69.0	74.0
2/7 -15/7	"	10.40	15.166	212.3	28	184.3	90	94.3	70.53	129.8	63.4	66.4
16/7 -29/7	"	10.20	14.833	207.7	28	179.7	90	89.7	74.1	133.1	66.7	66.4
30/7 -12/8	"	9.50	14.333	200.6	28	172.6	81.8	90.8	75.0	129.3	61.3	68.0
13/8 -26/8	"	9.15	13.75	192.5	28	164.5	90	74.5	60.9	100.0	54.7	45.3
27/8 - 9/9	"	8.35	13.083	183.2	28	155.2	90	65.2	70.8	109.7	63.6	46.1
10/9 -23/9	"	8.00	12.5	175.0	28	147.0	90	57.0	77.3	113.6	69.6	44.0
24/9 - 7/10	"	7.20	11.833	165.7	28	137.7	90	47.7	80.6	110.8	72.4	38.4
8/10-21/10	"	6.45	11.25	157.5	28	129.5	90	39.5	80.4	104.0	72.3	31.7
22/10- 4/11	"	5.30	10.0	140.0	21	119.0	90	29.0	73.2	87.1	65.9	21.2
5/11-18/11	7.45 a.m.	5.00	9.25	129.5	21	108.5	85.6	22.9	60.1	65.2	51.4	13.8
19/11- 2/12	"	5.00	9.25	129.5	21	108.5	82.0	26.5	56.8	61.5	46.5	15.0
3/12-16/12	"	5.00	9.25	129.5	21	108.5	82.0	26.5	44.4	48.2	36.4	11.8
(15 days)												
17/12-31/12	"	5.00	9.25	138.7	22.5	116.2	80.9	35.3	41.6	48.4	33.6	14.8
1/1 -14/1	"	5.00	9.25	129.5	21	108.5	75.1	33.4	35.9	38.9	27.0	11.9
15/1 -28/1	"	5.00	9.25	129.5	21	108.5	82.0	26.5	41.1	44.6	33.7	10.9
29/1 -11/2	7.30 a.m.	5.25	9.916	138.8	21	117.8	75.1	42.7	50.8	59.8	38.1	21.7
12/2 -25/2	"	5.55	10.416	145.8	21	124.8	89.8	35.0	45.9	57.3	41.2	16.1
(14½ days)												
26/2 -11/3	"	6.25	10.916	155.5	28.5	127.0	90.4	36.6	66.9	84.9	60.4	24.5
12/3 -25/3	"	7.10	11.666	163.3	28	135.3	88.8	46.5	71.7	96.8	63.5	33.3
26/3 - 8/4	"	8.20	12.833	172.7	28	144.7	82.9	61.8	77.7	112.1	64.2	47.9

Tot. N.T. Hrs. - Based on Agricultural Wages Board (Scotland) Combined Districts Wages Order No. 9 - operative date 18th April, 1966. From Schedule I, Clause 6 (1), observing Clause 7 (single day holidays), but not Schedule II Clause 1 (2) (annual holidays).

Meals - Deductions based on 1½ hrs. for lunch; ½ hr. for tea, on the assumption that if overtime is to be worked in the evening, only a short break will be taken.

W.D. % - This calculation being for "The Farm" the time availability is a composite of $\frac{(\text{Haddington \%} \times 2) + \text{N. Berwick \%}}{3}$.

The four Haddington farms total 1900 ac. and the two N. Berwick farms total 943 ac. i.e. Ratio = 2:1.

Av. Stop - The average time for each 14 day period at which work would stop i.e. 5.00 p.m., or dusk, whichever is the later. Dusk is taken as halfway between sunset and dark, as indicated for Latitude N 56° by the Smithsonian Met. Tables, and illustrated in Figure T.

N.B. - There are 15 days from 17/12 to 31/12 and an average of 14½ days from 26/2 - 11/3.

TABLE 44: WORKABLE TIME FROM 18TH APRIL, 1966.